W. P. Tufts

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

VOLUME 45

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OFFICERS AND COMMITTEES FOR 1945

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Vice-President......G. F. Potter

Sectional Chairman......F. P. Cullinan, *Pomology;* Ora Smith *Vegetable Crops;* J. C. Ratsek, *Ornamental Horticulture*

Secretary-Treasurer......H. B. Tukey

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J. H. MacGillivray, *Vice-Chairman*......C. L. Vincent, *Secretary*

GREAT PLAINS REGION (for 1944–45, elected June, 1942)

Harold Mattson, *Chairman*

P. D. Hargrave, *Vice-Chairman* M. F. Babb, *Secretary*

SOUTHERN REGION (for 1943–44, elected Feb. 1942)

W. S. Anderson, *Chairman* B. L. Wade, *Acting Secretary*

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W. B. Mack
H. B. Tukey
E. P. Cullinan
Ora Smith
J. C. Ratsek
Henry Hartman
W. S. Anderson
G. F. Potter (1945)
J. E. Knott (1946)

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J. S. Bailey
J. H. MacGillivray

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EDITORIAL COMMITTEE

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M. B. Davis (1945)
G. F. Potter (1946)
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E. C. Auchter

AUDITING COMMITTEE

J. D. Hartman
E. F. Palmer

NOMINATING COMMITTEE

C. J. Raleigh, *Chairman*
W. A. Aldrich
W. D. Kimbrough
Alex Laurie
E. R. Parker
P. W. Zimmerman

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and

*As revised and adopted at the Philadelphia meeting, January 1, 1941.

junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:*—There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

SOCIETY AFFAIRS

REPORT OF THE SECRETARY-TREASURER

The American Society for Horticultural Science met at Cleveland, Ohio at the Carter Hotel on Sept. 11, 12, and 13, 1944, this being the first general meeting of the Society since the meeting at Dallas, Texas, in December of 1941. Although there were times during this period of nearly 3 years when a meeting seemed almost imperative, the Society placed the issues of national interest first and accepted without question the request of the Office of Defense Transportation to avoid activities which might tend to overtax the transportation system of the country. Only when it was apparent that the situation justified a meeting was one held, namely, the one at Cleveland. The Society may feel rightly proud of its record and satisfied that matters have been handled as well as they have.

Your officers have carried on as best they knew how, under handicaps of labor shortage, priorities, paper shortages, censoring of scientific journals, and the usual run of delays and difficulties which have been experienced by everyone. Although the Proceedings have been slow at times, five volumes have been published since the Dallas meeting, and a sixth volume is in press. Society membership has reached an all-time high of 908, and the finances of the Society are a little ahead of what they were at the time of the Dallas meeting. It is to be hoped that from now on the annual meeting may be held regularly. To complete the record of group meetings held in 1943, the meeting at Tifton, Georgia, should be added to those listed in Volume 44 of the Proceedings.

The group meeting of 1943 helped to bridge the period of no meetings and were so successful that a committee is to be appointed to explore possibilities further.

The material published in the Proceedings has proved of such value to many practical workers in the horticultural field that it seems worthwhile to explore the possibility of increasing the circulation of the Proceedings and in so doing render a greater service to horticulture.

The Society has reached a size where it is no longer possible for one individual to handle all phases of activity and discharge all duties well. Accordingly it is suggested that a committee be appointed to look into the breaking down of the position of Secretary-Treasurer into four parts, such as: Editor, Business Manager, Secretary, and Treasurer.

Since the fiscal year of the Society is the calendar year, no complete report is presented at this time. The Society income, however, apparently continues to run a little ahead of expenditures.

H. B. Tukey
Secretary-Treasurer

BUSINESS MEETING, SEPTEMBER 14, 1944, 1:30 P. M. CARTER HOTEL, CLEVELAND, OHIO

The report of the Secretary-Treasurer was read and approved.

The report of the Executive Committee, as follows, was read and adopted:

1. The Committee has reviewed the suggestions received from the membership during the year regarding the welfare of the Society.

2. The Committee has reviewed matters of membership, the Secretary's report, the Treasurer's report, the financial condition of the Society and the publication of the Proceedings.

3. The Committee recommends that the Society make available to a wider group information regarding the possibility of associating with the Society as associate members. To further this recommendation it is further recommended that the Membership Committee and the regional Chairmen function towards this end during the ensuing year.

4 It is recommended that a committee be appointed by the President to survey the development of Regional Groups of the Society.

5. It is recommended that the Committee on Varieties and Nomenclature be continued another year.

6. Nominations by your committee for the Nominating Committee are: G. J. Raleigh, *Chairman;* W. A. Aldrich, W. D. Kimbrough, Alex Laurie, E. R. Parker, P. W. Zimmerman.

J. C. MILLER, *Chairman*

The Nominating Committee presented a list of nominations for officers and committees for 1945, in which were elected as listed on page vii.

Committee on Varieties and Nomenclature: After discussion of the entire question of varieties and nomenclature, including the importance of this problem to horticulture and the position of the ASHS in the matter, it was recommended that the committee of W. H. Alderman, Chairman; R. M. Brooks, Donald Wyman, V. R. Boswell, M. J. Dorsey, W. E. Lammerts, and M. B. Davis, be continued to study and advise in this field.

REPORT OF THE RESOLUTIONS COMMITTEE

WHEREAS, the following organizations and individuals have contributed greatly to the success of this meeting of the American Society for Horticultural Science, namely:

The officers of the American Association for the Advancement of Science who made the necessary arrangements for holding the meeting in Cleveland, and who furnished certain equipment and services.

The management of the Carter Hotel which has made us comfortable and provided excellent meeting places.

Dr. G. M. Darrow, Chairman of the Program Committee, who, with the members of the committee, arranged an interesting and timely program.

Dr. H. D. Brown of the University of Ohio who made the very satisfactory local arrangements for the meeting.

THEREFORE, BE IT RESOLVED that the Secretary, H. B. Tukey, be requested to write to each of these individuals and organizations expressing our appreciation for their assistance.

WHEREAS, the Division of Predator and Rodent Control, Fish and Wildlife Service, United States Department of the Interior, has carried out in the United States and especially in the fourteen northeastern states, important research and demonstrational work on the biology and control of field mice, rats, woodchucks, rabbits, and other animal and bird pests which has been of inestimable value to orchardists, foresters, farmers and nurserymen.

BE IT RESOLVED, that we express our approval of this work to the Division of Predator and Rodent Control, Fish and Wildlife Service, United States Department of the Interior, and

BE IT FURTHER RESOLVED, that we believe that the Service should be aided in expanding its program to include further study and research on the biology and control of wildlife pests which adversely affect growing crops and stored food supplies.

STANLEY JOHNSTON, *Chairman*
J. G. MOORE
W. P. JUDKINS

The Relation of Nitrogen Absorption to Nitrogen Content of Fruit and Leaves in Citrus

By WINSTON W. JONES, W. P. BITTERS, and ALTON H. FINCH, *University of Arizona, Tucson, Ariz.*

IN ALL citrus-producing areas fruit of some varieties and under some marketing conditions are carried on the tree through the next year's blooming period. For example, in Arizona grapefruit trees blossom in March and April depending upon locality. Fruit from this blossoming begins to ripen in October but may be carried on the tree until the following July so that another blossoming occurs while the fruit is still on the trees. Similarly Valencia orange trees blossom at about the same time as grapefruit and the majority are not harvested until more than 12 months later so that the next year's blossoming occurs before the fruit are off the tree.

Of recent years it has been found (3) that citrus trees must have a relatively high nitrogen content at blossoming time to produce a heavy crop of fruit. Hilgeman (1, 2) and Martin (3) have shown that nitrogen is taken up readily by citrus trees during the winter as well as during the summer. It has become a standard practice to apply nitrogen fertilizers during the winter months.

This practice has given rise to the question: Does the application of nitrogen during the winter affect the quality or grade of fruit being carried on the tree?

In 4 years of study of nitrogen relations in grapefruit Martin (3) observed that "winter nitrogen applications seem to have very little effect upon the quality of the fruit remaining upon the tree". However, this conclusion was based upon the observed behavior of the fruit on the trees under observation. No specific data were obtained. The present paper presents data on the influence of nitrogen applications upon the nitrogen content of the fruit.

MATERIALS AND PROCEDURE

The fruit for this study included Marsh grapefruit and Valencia oranges from two locations — the Salt River Valley Citrus Research Farm near Phoenix and the Yuma Mesa Citrus Farm near Yuma.

Salt River Valley Citrus Research Farm:—This citrus orchard was acquired by the University as a gift from the industry in the early spring of 1943. Prior to this time and throughout the spring and summer of 1943 it was given uniform treatment throughout. Thus during the flowering and growth of the fruit for the 1943–44 crop all trees were treated alike. During the winter of 1943–44 differential plot treatments were started. Among these plots one of both grapefruit and Valencias received nitrogen (ammonium sulfate 5 pounds per tree) applied on January 15, 1944. An immediately adjacent plot not only received no nitrogen but had a crop of winter barley grown and removed to further reduce the nitrogen available to the trees.

Fruit was harvested from both plots of grapefruit and Valencias on May 7, 1944. In the case of the grapefruit, five fruit from each of

eight trees in each plot were harvested, mixed, and then analyzed in lots of eight fruit. For the oranges, five fruit were harvested from each of ten trees and analyzed similarly.

Leaf samples were taken at the same time the fruit were harvested. Samples were obtained by taking 20 leaves from each of five trees — giving a total of 100 leaves per sample.

Yuma Mesa Citrus Farm:—On this farm plots differing in nitrogen level have been maintained for several years. Two of these plots were selected for this study. One had been maintained high in nitrogen. The other had been fertilized in the winter with nitrogen but during the summer nitrogen was withdrawn by use of a competing grass cover crop. Thus trees in this plot were high in nitrogen during the winter and early spring and low during the summer and fall.

Leaf and fruit samples were taken at intervals from September to April. Leaf samples were obtained by taking 20 leaves from each of five trees, giving a total of 100 leaves for each sample. Fruit samples consisted of four fruit from each of five trees in each plot on each sampling date.

Chemical determinations on samples from both locations were similar. Juice was removed from each fruit by an electric reamer. The peel was then dried in a circulating oven at 70 degrees C and ground and passed through a 60-mesh screen. The leaves were dried and ground in the same manner. Amount of nitrogen was determined by the Micro-Kjeldahl method.

Experimental Data and Discussion

Salt River Valley Citrus Research Farm:—Table I shows the nitrogen content of the fruit and leaves for both the Marsh grapefruit

TABLE I—Nitrogen in Juice, Peel, and Leaf of Citrus Following Nitrogen Fertilization

Kind of Citrus	Treatment	N of Juice Mg/100 Ml	N of Peel (Per Cent Dry Weight)	N of Leaf (Per Cent Dry Weight)
Marsh Seedless Grapefruit	Nitrogen	101.7	1.11	2.27
	No Nitrogen	104.6	1.11	1.78
Valencia Oranges	Nitrogen	139.1	1.15	2.38
	No Nitrogen	153.5	1.11	1.99

and Valencia oranges. The application of nitrogen produced a marked increase in the percentage of nitrogen in leaves of both the grapefruit and oranges after the application of nitrogen fertilizer. At the same time there was no increase in nitrogen in either the juice or peel of the fruit. In fact, the juice of the oranges receiving no nitrogen fertilizer was actually somewhat higher in nitrogen than where nitrogen was applied.

Clearly, the nitrogen applied was absorbed and moved into the leaves but did not enter the fruit.

Yuma Mesa Citrus Farm:—Fig. 1 shows the results obtained with the grapefruit at Yuma. Sampling from September to December revealed wide differences in nitrogen content of both leaves and fruit

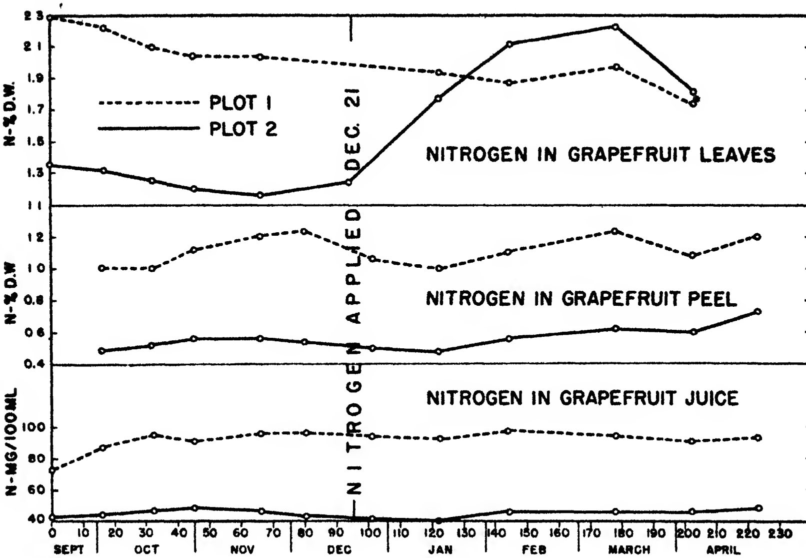

FIG. 1. Nitrogen in Marsh Seedless Grapefruit (juice, peel, and leaves) before and after nitrogen fertilization.

from the different plots. With the application of nitrogen on December 21, 1943, leaves of the plot which had been carried low in nitrogen promptly increased in percentage nitrogen but again there was no corresponding increase in nitrogen of the juice or peel of the fruit.

It is of interest, that while leaves from plot 2 which was low in nitrogen increased in percentage nitrogen with the application of nitrogenous fertilizer, those from the plot already high in nitrogen did not increase. The percentage nitrogen in the leaves of plot 2 became higher than that of plot 1. This is taken as indicating an influence of the nitrogen content of the tree upon the absorption of nitrogen.

INTERPRETATION AND CONCLUSIONS

It has been found that there was no increase in nitrogen in mature fruit on the tree following the application of nitrogen during the winter months. It is, therefore, concluded that the winter application of nitrogen does not contribute to the deterioration of fruit as it hangs on the tree during the winter and spring months.

It is believed that nitrogen enters the fruit only during its period of growth and development and that after a stage of maturity has been attained which roughly corresponds with "legal maturity" and harvestability, nitrogen will no longer enter the fruit regardless of the amount applied.

It is the nitrogen which has entered the fruit the previous summer which accounts for the rapid deterioration in market grade that is associated with high nitrogen nutrition (3).

Further evidence of the stability of the nitrogen content of the fruit is seen in the fact that nitrogen was not lost from it during the spring flush of growth as was the case of the leaves.

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Accumulation of Nitrogen from Different Sources by Peach Trees

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THERE is a perennial interest in the various materials used to supply nitrogen. One important phase of this question is the availability to the tree of the nitrogen from these materials. The study reported here is a preliminary evaluation of the accumulation in shoots and leaves of nitrogen from three sources, namely, ammonium sulfate, calcium nitrate and urea.[1] The trees used were 17-year-old Phillips Cling peaches growing in a Yolo loam soil at Davis, California, which had been previously unfertilized. Plots consisting of 10 trees each were fertilized September 25, 1939, with 8, 10, and 4 pounds of the above materials respectively, providing 1.6 pounds of actual nitrogen per tree in each case. The trees were given the regular cultural practices of the district.

Soil samples were taken at intervals to follow conversion to nitrate and movement in the soil. Ammonia nitrogen was determined in the ammonium sulfate and urea plots, and nitrate in all plots. Composite samples in 1-foot increments to 3 feet were made by using one core of a soil tube from near each of the ten trees in a plot.

The first rain after fertilizer application fell late in December. The seasonal total was 19.77 inches, nearly all of which had fallen by the end of April. Penetration was about 8 feet. No irrigation was given during the period considered.

During February and March, shoots were sampled at about 2-week intervals. Ten shoots were collected from each tree and composited.

TABLE I—NITRATE NITROGEN AND AMMONIA IN SOIL, IN PARTS PER MILLION OF DRY SOIL*

Treatment	Depth (Feet)	February 27		March 20		April 24	
		NH_3	NO_3^-	NH_3	NO_3^-	NH_3	NO_3^-
$(NH_4)_2SO_4$	0–1	292	78	262	91	20	25
	1–2	20	32	12	21	16	17
	2–3	15	12	12	14	11	15
$Ca(NO_3)_2$	0–1		25		19		14
	1–2		20		16		19
	2–3		17		17		21
$(NH_2)_2CO$	0–1	97	84	63	62	7	12
	1–2	23	65	15	45	9	9
	2–3	19	32	14	5	9	8
Check	0–1		23		19		16
	1–2		12		9		11
	2–3		9		11		5

*The first rain after fertilizer application fell late in December. The seasonal total was 19.77 inches, nearly all of which had fallen by the end of April.

[1]The writer wishes to extend his sincere appreciation and gratitude to Dr. E. L. Proebsting for his advice in the planning and carrying out of the investigation, and for helpful suggestions and careful perusal of the manuscript.

TABLE II—Percentage of Nitrogen Content of Wood and Bark of 1-Year Old Shoots of Peach Trees Fertilized the Preceding September

Treatment	Tissue	February 1	February 15	March 7	March 20
$(NH_4)_2SO_4$	Bark Wood	1.86 0.83	1.89 0.79	2.56 0.87	2.88 0.80
$Ca(NO_3)_2$	Bark Wood	2.04 0.77	2.05 0.87	2.60 0.96	2.95 0.98
$(NH_2)_2CO$	Bark Wood	2.03 0.83	2.06 0.69	2.70 0.65	3.03 0.67
Check	Bark Wood	2.04 0.84	2.04 0.75	2.30 0.80	2.54 0.82

On the last date, March 20, the trees were blossoming, and the blossoms were discarded. Wood and bark were separated and analyzed separately for total nitrogen.

Leaves were collected from April 9, when the basal ones had nearly reached full size, at 2-week intervals until the end of May. Thirty leaves per tree were composited for each sample.

Plant samples were dried at 60 degrees C and ground. The Kjeldahl method was used for total nitrogen determinations.

The results of the soil analyses are presented in Table I. These data confirm the usual observations of fixation of NH_4^+ in the surface soil, followed by nitrification and leaching of NO_3^-. There seems to have been a considerable conversion of urea to ammonia before the winter rains could leach it. The nitrate seems to have been leached below the third foot by the time sampling commenced. A month after growth began, the nitrate had been reduced to about the same level in all plots, including the check.

TABLE III—Percentage of Nitrogen Content of Peach Leaves from Trees Fertilized the Preceding September

Treatment	April 9	April 19	May 1	May 15	May 29
$(NH_4)_2SO_4$	5.08	4.28	3.89	3.54	3.11
$Ca(NO_3)_2$	5.08	4.14	3.88	3.30	3.15
$(NH_2)_2CO$	5.07	4.02	3.72	3.32	3.01
Check	4.88	3.86	3.42	2.81	2.42

Shoot analyses showing total nitrogen are presented in Table II and Fig. 1. It will be noted that all plots were nearly identical at the first two dates of sampling. On March 7, all of the bark samples increased notably, the fertilized plots gaining about double the increase found in the check. Two weeks later, at blossoming, there had been a further increase, of uniform magnitude for the fertilized plots, and somewhat less for the check. The total increase for the month ending at blossoming amounted to about 50 per cent for the fertilized and 25 per cent for the check trees. Nitrogen in the wood was much lower, less consistent, and showed little evidence of change. The fact that the bark of these shoots showed notable increases in nitrogen before leafing is very interesting, confirming the findings of Aldrich (1)

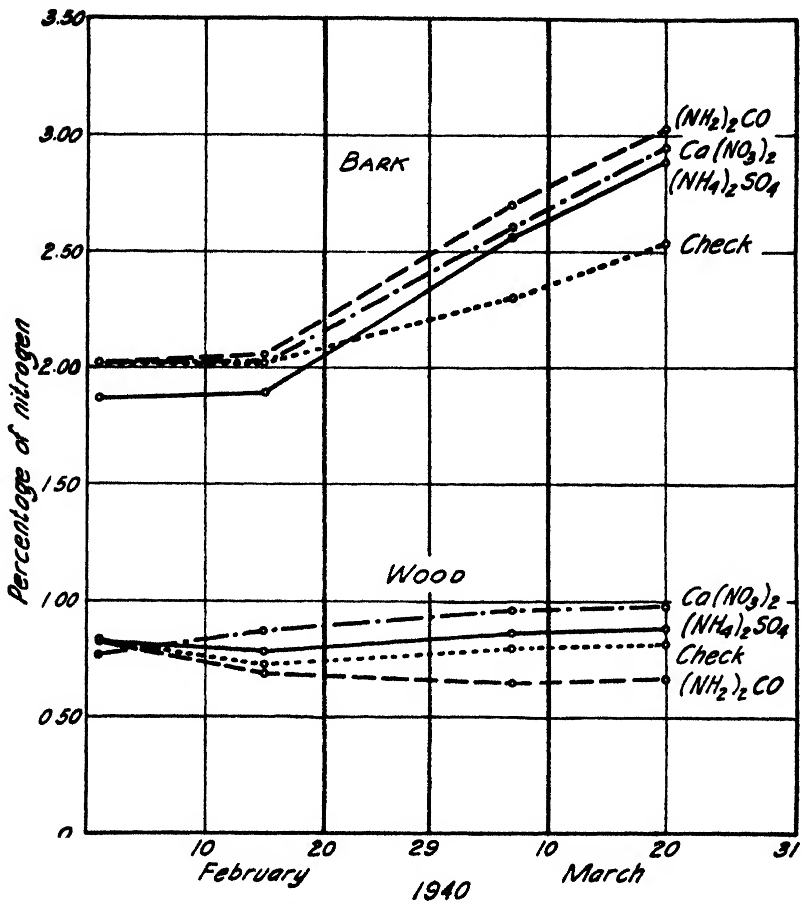

FIG. 1. Total nitrogen content of wood and bark of 1-year old shoots of peach trees fertilized the preceding September.

with apple, and is suggestive in connection with current theories of translocation.

The nitrogen content of the leaf samples is shown in Table III and Fig. 2. There was good agreement among the fertilized plots throughout the period sampled. There was a differential between the check and treated leaves throughout, but the rate of seasonal decrease was retarded in the fertilized plots. In both absolute and relative terms, the nitrogen content dropped faster in the check than in the fertilized plots.

The close correspondence between the three sources of nitrogen is interesting in view of the time of application. The nitrate was largely removed from the surface three feet, and it is to be presumed from the work of Aldrich that little absorption took place during the early winter. It was evidently not leached below the zone of effective

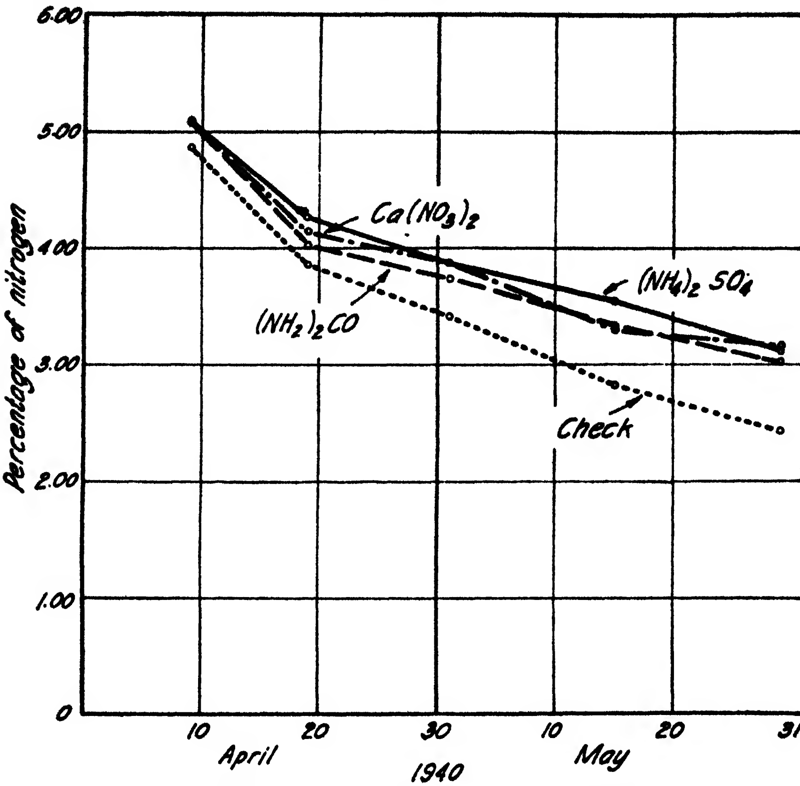

FIG. 2. Total nitrogen content of peach leaves from trees fertilized the preceding September

absorption by the roots. The other sources had been made available by nitrification and leaching into the root zone so that there was no difference in the mobilization in the shoots from pre-bloom through the early stages of growth.

SUMMARY

The appearance of nitrogen in 1-year old shoots of peach from three nitrogen sources following autumn fertilizer application was simultaneous, and of the same order of magnitude. The seasonal decline in the nitrogen content of leaves was less in fertilized trees than in unfertilized ones, both in absolute and relative terms during the 10 weeks following blossoming. A notable increase in the nitrogen content of shoot bark before blossoming indicates extensive upward movement of nitrogen before there is appreciable transpiration.

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The Influence of Differential Fertilization with Ammonium Sulfate on the Chemical Composition of McIntosh Apple Leaves

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REPORTS previously published have suggested the usefulness and some of the limitations of chemical analysis of leaves in the diagnosis of nutritional problems of the McIntosh apple tree. Analyses of leaf samples from McIntosh trees deficient in, and from trees responding to, potassium, magnesium and nitrogen have been recorded (2, 4, 6). The ranges in per cent dry weight potassium, magnesium, calcium and phosphorus found in leaves from a large number of New York McIntosh orchards, together with fluctuations due to season, and the trends within one season have been studied (5). The reciprocal relationship between potassium and magnesium in McIntosh apple leaves has been indicated (3). This paper summarizes a study of the influence of nitrogen fertilization on percentages of nitrogen, potassium, magnesium, calcium, phosphorus, and ash found in the dry weight of McIntosh apple leaves.

PROCEDURE

The leaf samples analyzed were taken in July 1943 from five experimental orchards to which ammonium sulfate had been applied at certain rates in April 1942 and April 1943.[1] Prior to the fertilization of April 1942 the trees in each orchard had been grouped in blocks of two or three according to uniformity of size and appearance, the number of trees per block depending on the number of fertilizer treatments to be made. In the Losee orchard there were 10 pairs of experimental trees; in the Forrence orchard there were 17 blocks of three trees; and in the other three orchards, 20 blocks of three trees were used. The samples consisted of 50 leaves selected at random from the middle portion of shoots located on the outside of each experimental tree. They were dried to constant weight at 65 degrees with forced draft and ground to pass a 40-mesh sieve. Total nitrogen was determined by the Kjeldahl method, and the other determinations were made in duplicate according to the general procedure of Peech (14).

DESCRIPTIONS OF ORCHARDS

Some pertinent facts about the experimental plots are summarized in Table I. The Shannon and Losee orchards supported only light sod cover whereas volunteer grass cover was heavy on the other three orchards. The light cover was due mostly to the low water-holding capacities of Dunkirk very fine sandy loam and Hoosic gravelly loam soils on which these orchards were located. Both soils permit very

[1]Certain phases of this study have been presented previously (2, 18).

TABLE I—DESCRIPTIONS OF EXPERIMENTAL ORCHARDS

Location, and Soil Type	Trees Per Treatment	Age (Years)	Orchard Cover	Treatment (Pounds $(NH_4)_2SO_4$ Per Tree)	1943 Crop (Bushels Per Tree)	Relative Color of Leaves When Sampled
			Forrence			
Champlain Valley Dover loam	17	17	Heavy sod	10	10.9	Dark
				5	10.2	Dark
				0	8.5	Light
			Shannon			
Western New York Dunkirk v. f. sandy loam	20	20	Light sod	7½	18.8	Dark
				5	19.3	Moderate
				2½	15.2	Light
			Kappel			
Western New York Ontario loam	20	13	Heavy sod	7½	5.3	Dark
				5	5.8	Dark
				2½	4 5	Dark
			Clark			
Hudson Valley Cossayuna gravelly loam	20	17	Heavy sod	12	21.8	Dark
				8	19.6	Dark
				4	17.4	Moderate
			Losee			
Hudson Valley Hoosic gravelly loam	10	26	Light sod	8	9.0	Moderate
				4	5 9	Light

deep rooting and trees growing on them seem to be very sensitive to small differences in rate of nitrogen fertilization. In 1943 the yields in the Kappel and Losee orchards were far below the bearing capacities of the trees. Poor pollination weather in the Kappel plot and light bloom in the Losee plot apparently were the reasons for those low yields. In all except the Kappel orchard, there was a noticeable difference in 1943 vegetative growth, fruit yield, and leaf color between the highest and lowest nitrogen treatments. In the Kappel orchard the trees of all treatments appeared highly vegetative and while there was a significant difference between the highest and lowest N fertilization plots in leaf nitrogen (Table II), the difference was rather small and the N percentage of the lowest nitrogen trees was higher than the N percentage of the highest nitrogen trees in any of the other orchards. There are three possible causes for this: (a) the trees were younger and smaller than those of the other orchards; (b) the crop was lighter than in the other orchards; (c) in May and June 1942 the owner cultivated all of the plots twice with a heavy spring tooth harrow, and the trees in all plots were highly vegetative throughout 1942. Perhaps more than one of these possible causes is involved.

RESULTS

The chemical analyses are summarized in Table II, and for the Clark, Shannon and Forrence orchards, in Figs. 1, 2, 3, and 4.

In all except the Kappel orchard, the average leaf weight was significantly less for the samples from low nitrogen trees than in those from the high nitrogen trees.

TABLE II—Chemical Composition of Leaf Samples from 5 McIntosh Apple Orchards on Which Nitrogen Fertilizer Was Used at Different Rates. 1943

Treatment (Pounds $(NH_4)_2SO_4$ Per Tree)	Av Dry Wt Per Leaf (Gms)	LD 5 Per Cent*	N	LD 5 Per Cent*	K	LD 5 Per Cent*	Mg	LD 5 Per Cent*	Ca	LD 5 Per Cent*	P	LD 5 Per Cent*	Ash	LD 5 Per Cent*
Forrence														
10	0.452		2.23		1.06		0.34		1.46		0.18		6.62	
5	0.440		2.15		1.14		0.33		1.44		0.18		6.81	
0	0.384		1.77		1.39		0.31		1.32		0.22		6.83	
		0.025		0.08		0.12		0.03		0.14		0.02		0.49
Shannon														
7½	0.428		2.18		1.25		0.27		1.36		0.17		6.39	
5	0.416		2.05		1.37		0.25		1.34		0.17		6.54	
2½	0.402		1.84		1.48		0.23		1.25		0.19		6.45	
		0.021		0.07		0.12		0.02		0.08		0.01		0.30
Kappel														
10	0.398		2.42		1.10		0.34		1.26		0.18		5.95	
5	0.398		2.39		1.12		0.33		1.35		0.18		6.18	
2½	0.402		2.28		1.13		0.34		1.31		0.18		6.20	
		0.037		0.05		0.10		0.01		0.10		0.01		0.26
Clark														
12	0.354		2.14		1.80		0.23		1.17		0.18		7.28	
8	0.334		2.06		1.86		0.22		1.11		0.19		7.12	
4	0.334		1.93		1.87		0.22		1.14		0.21		7.37	
		0.021		0.07		0.19		0.01		0.09		0.01		0.26
Lowe														
8	0.370		1.99		1.41		0.26		1.14		0.21		6.29	
4	0.334		1.83		1.53		0.24		1.14		0.23		6.49	
		0.022		0.13		0.14		0.03		0.11		0.03		0.31

*Least difference for statistical significance with odds of 19:1.

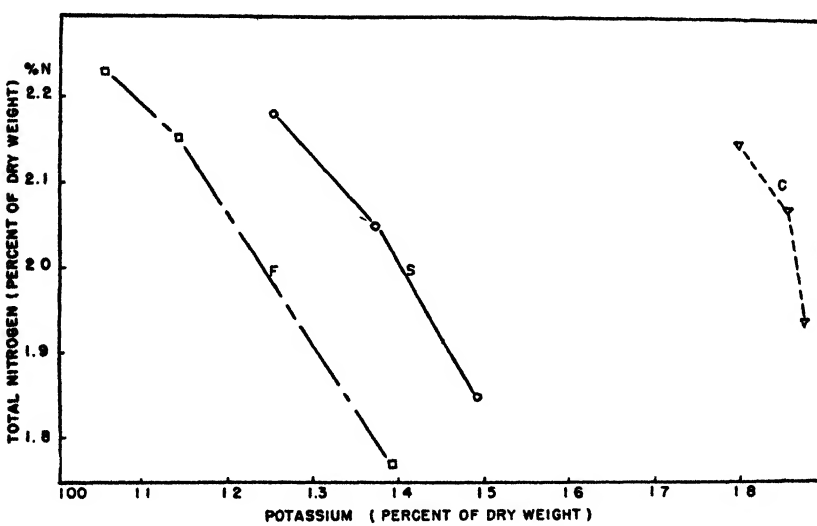

Fig. 1. The relation between total nitrogen and potassium in leaf samples from three McIntosh apple orchards. (F = Forrence; S = Shannon; C = Clark. For rates of nitrogen fertilization, see Table II).

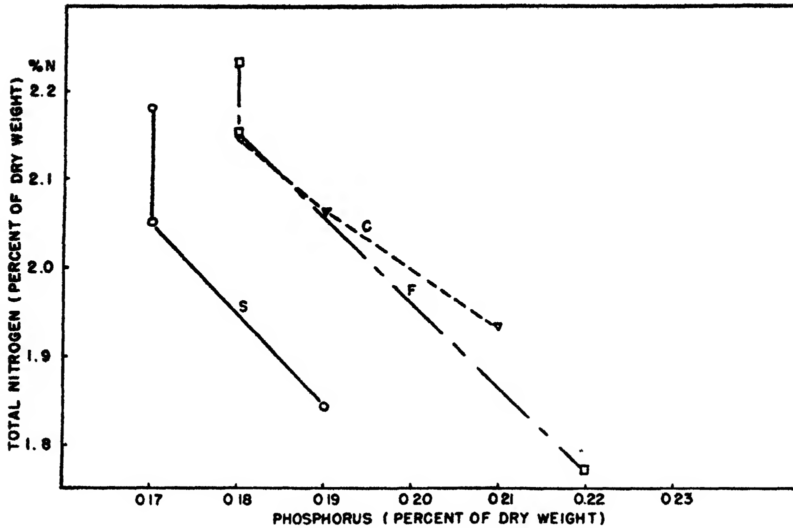

FIG. 2. The relation between total nitrogen and phosphorus in leaf samples from three McIntosh apple orchards. (F = Forrence; S = Shannon; C = Clark. For rates of nitrogen fertilization, see Table II).

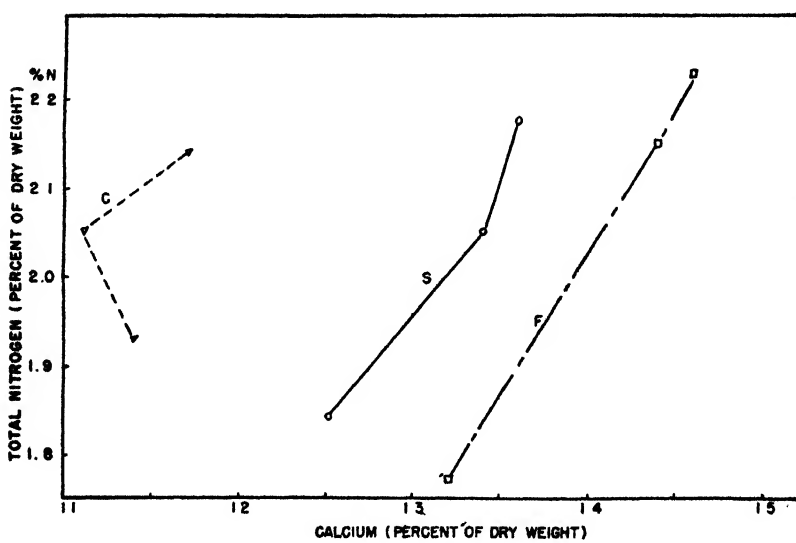

FIG. 3. The relation between total nitrogen and calcium in leaf samples from three McIntosh apple orchards. (F = Forrence; S = Shannon; C = Clark. For rates of nitrogen fertilization, see Table II).

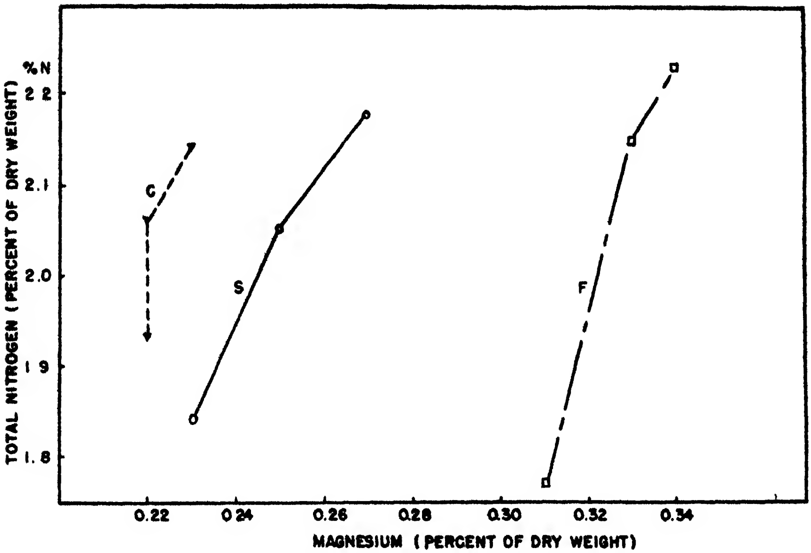

FIG. 4. The relation between total nitrogen and magnesium in leaf samples from three McIntosh apple orchards. (F = Forrence; S = Shannon; C = Clark. For rates of nitrogen fertilization, see Table II).

Leaf nitrogen varied directly with nitrogen fertilization. All differences were significant except that between the 10-pound and 5-pound treatments in the Kappel orchard.

In all the orchards, the average K content was increased with a decrease in the amount of N applied. But the potassium differences due to nitrogen fertilization were statistically significant at odds of 19:1 only in the Shannon and Forrence plots.

In all but the Kappel orchard, per cent leaf Mg increased with increasing N fertilization and leaf nitrogen. But the trends were statistically significant only in the Forrence, Shannon and Clark plots.

Calcium percentages, like magnesium, seemed to vary directly with nitrogen. However, differences in calcium between leaf samples from high and low nitrogen treatments were significant only in the Forrence and Shannon plots, the intermediate N treatments in the Kappel and Clark orchards did not follow this trend and there was no difference in the mean calcium percentage in the leaf samples from the two nitrogen treatments of the Losee plot.

Phosphorus percentages varied inversely with nitrogen treatment in all except the Kappel plot. The differences between the mean percentages of P in samples from high and low N treatments were significant at the Forrence, Shannon and Clark orchards.

While there seemed to be a tendency for per cent ash to vary inversely with nitrogen treatment, none of the differences was significant at odds of 19:1.

Discussion

Fig. 1:—The relation between per cent nitrogen and per cent of potassium in the Forrence, Shannon and Clark leaf samples is graphed in Fig. 1.

It was found in the Shannon orchard that leaves from the trees receiving 7½ pounds of ammonium sulfate contained 2.18 per cent N and 1.25 per cent K while leaves from trees receiving only 2½ pounds of this fertilizer 1.84 per cent N but 1.48 per cent K. In other words, there was an increase in leaf potassium percentage of 16 per cent associated with the lower rate of nitrogen fertilization. Similarly in the Forrence orchard, the highest rate of nitrogen fertilization produced leaves containing 2.23 per cent N and 1.06 per cent K, while trees receiving no fertilizer produced leaves containing 1.77 per cent N and 1.39 per cent K. Here the leaves from the unfertilized trees contained a third more potassium (as per cent of dry weight) than the leaves from the trees receiving 10 pounds of ammonium sulphate annually. In both of these orchards the effects of differential nitrogen on leaf potassium were highly significant statistically and were large in magnitude. In the Forrence orchard, where there were incipient potassium deficiency symptoms on some of the trees in the medium and high-nitrogen treatments, the visible symptoms were not apparent on the low-nitrogen trees, and leaf potassium at 1.39 per cent, was well above the "threshold" level of 1 per cent, previously proposed (17). Low nitrogen obscured the visible and analytical symptoms of potassium deficiency. On the other hand, in the Clark orchard, a difference in leaf nitrogen of 0.21 per cent was associated with a difference in mean leaf potassium of only .07 per cent. This amounted to 4 per cent of the largest K figure and was not statistically significant. Two differences between the Clark plot and the other two should be kept in mind: (a) the low nitrogen trees were higher in leaf nitrogen and appeared more vegetative than the low-nitrogen trees on the other two plots; (b) leaf potassium was much higher in all treatments of the Clark plot than in the other plots. Possibly both of these conditions tended to minimize the reduction in percentage K due to increasing N in the Clark orchard.

Figs. 2, 3, and 4:—For the leaf samples from these same three orchards, the inverse relationship between the percentages of P and N and the positive relationships between percentages of Ca and N and between percentages of Mg and N are graphed in Figs. 2, 3, and 4. All differences associated with high and low nitrogen treatments were significant at odds of 19: 1 except the calcium percentages for the Clark orchard. The differences tended to be greater in the samples from the Forrence and Shannon orchards than in those from the Clark orchard and were large enough (between 10 and 18 per cent of the highest figure) to indicate that an abnormally high or low nitrogen level in an orchard might obscure or accentuate chemical evidence of deficiency of one of these three nutrient elements.

Explanations for These Nitrogen Effects on Leaf Composition

N-K and N-P:—The reciprocal relationships of nitrogen and potassium and of nitrogen and phosphorus could be most easily explained in either or both of two ways: (a) increased vegetative growth and fruiting due to nitrogen fertilization could cause a lower concentration of potassium and phosphorus per unit leaf weight if the intake of those elements did not keep pace with the increase in weight of new tissue. (b) Ion competition directly or indirectly resulting from nitrogen fertilization could cause a reduction in absorption of K and P.

Certainly dilution is at least partly responsible for the differences in leaf potassium and phosphorus percentages. When the results for the Forrence, Shannon and Clark plots are expressed as milligrams per leaf (Table III) on the basis of the average dry weight of a leaf, the differences become less and in some cases disappear. Since increasing nitrogen increased the number of leaves, and the amount of shoot, root and girth growth (2) expression of the results on the basis of weight per tree would have decreased the differences still more, and in some cases the trends might have been reversed.

TABLE III—Composition of Leaves from the Forrence, Shannon, and Clark Orchards Expressed as Milligrams Per Leaf

Treatment (Pounds $(NH_4)_2SO_4$ Per Tree)	N	K	Mg	Ca	P	Ash
			Forrence			
10	10.08	4.79	1.54	6.60	0.81	29.92
5	9.46	5.02	1.45	6.34	0.81	29.96
0	6.80	5.34	1.19	5.07	0.85	26.22
			Shannon			
7½	9.33	5.35	1.16	5.82	0.73	27.37
5	8.53	5.70	1.04	5.57	0.71	27.20
2½	7.40	5.95	0.92	5.03	0.76	25.93
			Clark			
12	7.58	6.37	0.81	4.14	0.64	25.77
8	6.88	6.21	0.73	3.71	0.63	23.78
4	6.45	6.25	0.73	3.81	0.70	24.62

While absorption of potassium by plants has been found to decrease when nitrogen is supplied in ammonium salts rather than as nitrates (15), it seems doubtful that this phenomenon could have contributed materially to the inverse relationship between per cent N and per cent K in the leaves. One would expect nitrification to take place very rapidly in well-aerated surface soils under the conditions of optimum moisture prevailing in late April and May. Furthermore altho the presence of NH_4 ions would be expected to decrease absorption of Ca and Mg as well as K, intake of those ions seems to have increased in the trees most heavily fertilized with ammonium sulfate.

There is a considerable amount of evidence in the literature suggesting that potassium fertilization increases the absorption of nitrogen (7, 8, 13). On the basis of such studies one would expect leaf K

to vary directly with leaf N, and not inversely. On the other hand, there seems to be rather general agreement (1, 8, 9, 10, 11, 13, 16) that an inverse relationship exists between nitrogen and phosphorus in plants, and several of these workers suggest that the inverse relationship is due in part to anion competition.

N-Ca and N-Mg:—The direct relationships of leaf nitrogen and calcium and of leaf nitrogen and magnesium could be most easily explained in either or both of two ways: (a) these elements were absorbed by the apple roots more readily in association with nitrate or sulfate ions than otherwise and (b) replacement of Ca and Mg in the exchange complex by hydrogen as a result of ammonium sulfate fertilization increased the concentration of Ca and Mg ions in the soil solution. The higher the application of ammonium sulfate the more calcium and magnesium in the soil solution; the greater the concentration of these ions in the soil solution the greater the quantity absorbed by the apple tree roots. Support for the former idea is found in the work of Hoagland (10) and Nightingale (13) among others. The effect of ammonium sulfate in causing appearance of relatively large quantities of calcium and magnesium in soil drainage water is indicated in the work of Morgan and Bailey (12). However, potassium would act in the same way as calcium and magnesium in both of these reactions, and if they are involved it is difficult to understand why potassium varied inversely with nitrogen at the same time that calcium and magnesium varied directly with nitrogen.

It seems clear that a field study of the kind reported here cannot throw much light on the reasons for these nitrogen effects on leaf composition. More carefully controlled work in which all parts of the trees are analyzed, and in which the nutrient medium is studied more thoroughly will be necessary before the possible causes may be well evaluated.

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Effect of Season of Pruning and Number of New Shoots on the Rate of Top Regeneration of Valencia Orange Trees

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The present paper is the fourth in a group reporting upon the effects of time (4), severity (3), and number of new shoots on the rate of top regeneration of pruned citrus trees. It presents the results of a study designed to determine the effect of limiting the number of new shoots on Valencia orange trees pruned in early spring and early autumn of two succeeding years.

Material and Methods

The 64 Valencia orange trees used for this study were planted in the orchard in May 1930. They were part of the same lot which furnished materials, in whole or in part, for two previous studies (3, 4). They were propagated by budding carefully selected nucellar seedlings of a sweet orange clone with buds all from one Valencia orange tree. The trees were all in good health, comparatively uniform in size and appearance and were all in the same crop phase. They were temporary trees in a double planted block and were, when the experiment was started, beginning to crowd slightly.

Four lots of 16 trees each were pruned in early spring (February 28–March 15) and early autumn (August 30–September 15) of 1938 and 1939 respectively. The pruning was comparable to that described as "heavy" in a previous paper (3). It involved removal, including the leaves, of approximately four-fifths of the weight of the top. (Table I, Column 7). Five scaffold branches about 18 inches long were left to regenerate a new top.

After pruning, each group of 16 trees was divided into three lots. In 1938 six trees of each of the spring and autumn pruned groups were allowed to regenerate one new shoot on each of the five scaffold branches. All other new shoots were prevented from development by early removal at frequent intervals. Another six trees of each group were allowed to regenerate two new shoots on each scaffold branch, a total of 10 per tree. The remaining four trees of each group were allowed to regenerate an unrestricted number of new shoots. The treatments were similar in 1939 except that in place of the 5-shoot treatment six trees of each group were allowed to develop four new shoots on each scaffold branch, a total of 20 new shoots per tree. The 10-shoot and unrestricted groups were handled as in the previous year.

Beginning approximately 3 months after pruning, and at 3- to 6-week intervals for the restricted and 12-week intervals for the unrestricted, one tree of each lot was excavated either completely or by a "short-cut" method earlier described (3) which involved removal of all roots more than 0.8 centimeter in diameter. Total root weights for the "short-cut" trees have been adjusted by calculation to cor-

respond to those removed completely. Total tree weight was calculated by adding the weight of prunings to the weight of the tree, exclusive of new top, at the time of digging. We believe that changes in weight of residual parts of the tree between pruning and excavation were so slight that they may safely be ignored.

At the time of excavation determinations were made of the length and weight of new shoot growth and of weight and number of leaves, approximately by growth cycles. Samples of both new growth and residual parts of the tree were preserved for subsequent chemical and microchemical studies.

Data and Discussion

All data relating to the 64 trees which are pertinent to the present discussion are presented in Table I.

TABLE I—Effect of Season of Pruning and Number of New Shoots on the Rate of Regeneration of New Top of Heavily Pruned Valencia Orange Trees

(All Values refer to Fresh Weight in Grams)

Date of Excavation	Weeks following Pruning	Tree			Prunings		New Top				Leaves	
		Total	Above Ground	Trunk and Branches	Weight	Per Cent of Above Ground	Total Weight	Weight Per Shoot	Per Cent of Prunings	Per Cent Trunk and Branches	Total Weight	Per Cent of Total
1	2	3	4	5	6	7	8	9	10	11	12	13
					Pruned March 15, 1938 *Five-Shoot*							
5/6/38	8	138938	114342	20900	93442	81.7	143	29	0.2	0.7	57	0.04
7/26/38 .	19	127145	100010	14733	85277	85.2	885	177	1 0	6.0	743	0.6
10/7/38...	30	116656	92869	18479	74390	80.1	3599	720	4 8	19.4	2829	2 4
1/13/39 .	44	146185	110593	20780	89813	81.2	6614	1322	7.4	31.8	4583	3.1
3/16/39 .	53	146700	110447	18820	91627	82.9	7000	1400	7.6	37.2	4800	3 3
5/18/39 .	62	124331	98622	16520	82102	83.2	7900	1580	9.6	47.8	6322	5.0
Average	—	133326	104480	18372	86109	—	—	—	—	—	—	—
					Ten-Shoot							
6/14/38	13	154155	123804	21744	102060	82 4	320	32	0.3	1 5	231	0.1
10/28/38	33	143383	114733	21745	92988	81 0	6496	649	0.7	29 8	4730	3.3
12/22/38.	40	156566	127302	20706	106596	83.7	5792	579	3.8	27 9	4052	2.6
2/24/39 ..	49	153402	116863	20700	96163	82.2	7655	765	8 0	36.9	5747	3.7
4/27/39 .	58	143158	108586	19680	88906	81.8	10027	1003	11.3	50.9	6932	4 8
8/8/42	229	168603	126195	32300	93895	74.4	84420	8442	89 9	261.0	34540	20.5
Average ..	—	153211	119580	22813	96768	—	—	—	—	—	—	—
					Unrestricted							
9/2/38.	25	130606	109182	18462	90720	83.0	10207	57	11.3	55.2	8095	6.1
11/18/38	36	123824	94800	16781	78019	76.6	12018	334	15.4	71.6	8365	6.8
2/2/39 .	46	132460	101782	18320	83462	82.0	13005	295	15.6	70.9	9297	7.0
4/6/39 .	55	127741	95199	17180	78019	81.9	14308	511	18.3	83.2	10003	7.8
Average	—	128658	100241	17686	82555	—	—	—	—	—	—	—
					Pruned August 30, 1938 *Five-Shoot*							
12/9/38...	15	160703	124030	22424	101606	81.9	213	43	0.20	0.9	155	1.0
3/2/39....	26	162796	129070	22380	106690	82 6	206	41	0.19	0.9	157	1.0
5/4/39 ..	34	168500	132991	23220	109771	82.5	1308	262	0.11	5.6	1152	0.7
7/6/39. .	43	153012	118664	21140	97524	82.1	2883	577	3.0	13.6	2371	1.5
9/7/39..	52	186898	137301	22540	114761	83.5	7603	1521	6.6	33.7	5628	3.0
11/10/39..	61	189648	141580	23540	118040	83.3	14086	28171	11.9	59.8	10240	5.4
Average..	—	170259	130606	22540	108065	—	—	—	—	—	—	—

TABLE I—(*Concluded*)

Date of Excavation	Weeks following Pruning	Tree			Prunings		New Top				Leaves	
		Total	Above Ground	Trunk and Branches	Weight	Per Cent of Above Ground	Total Weight	Weight Per Shoot	Per Cent of Prunings	Per Cent Trunk and Branches	Total Weight	Per Cent of Total
1	2	3	4	5	6	7	8	9	10	11	12	13
Ten-Shoot												
1/20/39...	20	168850	134521	19760	114761	85.3	368	37	0.32	1.9	281	0.2
3/24/39 ..	29	251230	210308	27356	182952	86.9	533	53	0.29	1.9	401	0.2
5/25/39 .	38	135086	104743	19920	84823	80.9	3705	370	4.4	18.5	2928	2.2
7/28/39. .	46	183636	135272	24140	111132	82.1	10277	1028	9.2	42.5	8042	4.4
9/29/39 .	55	164084	123759	23060	100699	81.3	13017	1302	12.9	56.4	9560	6.0
12/22/39 .	67	182577	140721	25960	114761	81.5	15151	1515	13.2	58.4	9818	5.4
Average	—	180911	141554	23366	118188	—	—	—	—	—	—	—
Unrestricted												
2/9/39....	23	149062	113340	18000	95340	84.1	1510	15	1.5	8.3	1135	0.8
4/13/39. .	32	174267	138270	22500	115770	83.7	1970	30	1.7	8.7	1646	0.9
6/8/39 ..	39	179039	140442	24320	116122	82.6	5835	54	5.0	23.9	4720	2.6
10/20/39.	58	151754	109960	19240	90720	82.5	11754	289	12.9	61.1	8550	5.6
Average .	—	163531	125503	21015	104488	—	—	—	—	—	—	—
Pruned February 28, 1939 *Ten-Shoot*												
6/30/39 ..	17	145314	111020	20300	90720	81.7	891	89	1.0	4.4	697	0.5
8/31/39...	26	173576	128942	22800	106142	82.3	4136	414	3.9	18.1	3087	1.8
11/3/39 ..	35	150885	112994	21820	91174	80.6	9278	928	10.2	42.5	6860	4.5
1/5/40 ...	44	174974	134178	24860	109318	81.4	9571	957	8.7	38.5	7000	4.2
3/8/40 .	53	158961	109832	21380	88452	80.5	10655	1065	12.0	49.8	7332	4.6
5/8/41 . .	113	158989	117794	25260	92534	78.5	37745	3774	40.8	149.0	20705	13.0
Average	—	160450	119126	22737	96390	—	—	—	—	—	—	—
Twenty-Shoot												
7/20/39 ..	20	162158	118024	20500	97524	82.6	3232	162	3.3	15.2	2603	1.6
9/22/39 .	29	144895	103789	20780	83009	79.9	7251	362	8.7	34.8	5266	3.6
12/1/39	39	176864	129888	24560	105328	81.0	11447	572	10.9	46.6	7980	4.5
2/2/40 .	48	168813	128527	25560	102967	80 1	12138	607	11.8	47.4	8810	5.2
5/8/41	113	151457	111465	23920	87545	78 5	41612	2080	47.5	173.0	22557	14.9
8/10/42 .	178	176073	132772	32980	99792	75 1	106020	5301	106 0	321 4	51651	29.3
Average	—	163377	120744	24717	96028	—	—	—	—	—	—	—
Unrestricted												
8/10/39. .	23	145017	104534	23340	81194	77 6	10277	89	12.7	44.0	7838	5.4
10/13/39 .	32	142860	104844	18660	86184	82 2	10713	510	12 4	57 4	7756	5.3
12/15/39	41	191972	143530	25140	118390	82.4	16709	398	14 1	66.4	11714	6.1
4/4/40	57	170374	127207	24240	102967	80.9	21264	559	20.7	87.7	14633	8.6
Average	—	162556	120029	22845	97184	—	—	—	—	—	—	—
Pruned September 15, 1939 *Ten-Shoot*												
1/26/40. .	19	183062	139926	26980	112946	80.7	507	51	0.4	1.9	404	0.2
4/26/40. .	32	205362	153080	28340	124740	81.4	2603	260	2.1	9.2	1837	0.9
8/2/40	46	217562	166548	28200	138348	83 0	7133	713	5.2	25.2	5525	2.5
11/1/40..	59	177530	145010	25260	119750	82.5	14541	1454	12.1	57 5	11611	5.4
2/7/41	73	172862	133337	25380	107957	80.9	14547	1455	13.5	57.3	9434	5.5
3/28/41	80	177426	137406	24460	112946	82.1	15334	1533	13.6	62.6	10074	5.7
Average	—	188967	145885	26437	119447	—	—	—	—	—	—	—
Twenty-Shoot												
2/23/40...	23	193502	171876	31260	140616	81.8	871	44	0.6	2.8	664	0.3
6/7/40	38	236338	188486	31540	150946	83.2	6363	318	4.1	20.1	4869	2.1
8/30/40 .	50	199888	155942	27120	128822	82.6	12515	626	9.7	46.1	9135	4.6
9/13/40 .	52	185493	143449	26420	117029	81.5	12838	642	9.5	48.5	8076	4.4
11/22/40	62	198699	154214	27660	126554	82.0	16471	823	13.0	59.5	11331	5.7
4/4/41	81	179342	143822	27700	116122	80.7	23062	1153	12.6	83.2	14626	8.2
Average	—	198877	159631	28617	131015	—	—	—	—	—	—	—
Unrestricted												
3/29/40 ..	28	215883	161573	26400	135173	83.6	2439	12	1.8	9.2	1838	0.8
7/12/40 .	43	198378	161809	27090	134719	83 2	12198	222	9.1	45.0	9610	4.8
9/20/40 ..	52	219464	175346	29740	145606	83.0	17733	492	12.1	59.6	12185	5.6
4/11/41. .	82	174412	135298	24620	110678	81.8	23146	1218	20.9	94.0	15266	8.8
Average...	—	202034	158506	26963	131544	—	—	—	—	—	—	—

As previously reported (4), pruning does not greatly affect the periodicity of length growth of new shoots. At Los Angeles the periods of active growth occur mainly in February-March, July-August and October-November. In the intervals between those periods of activity length growth ordinarily does not occur.

New shoots were visible within 2 to 3 weeks after the spring pruning; the time interval was considerably longer for the autumn pruned trees. In both cases the period of length growth of new shoots was approximately coincident with that of neighboring unpruned trees. New shoots on both pruned and unpruned trees behaved similarly with respect to cessation of length growth and the shedding of the terminal growing tips.

The length of shoots produced during the first growth cycle was not greatly influenced either by the number of new shoots or the season of pruning. Except on the 10-shoot and 20-shoot trees pruned in the spring of 1939, which will be referred to later, most of the new shoots were from 40 to 50 centimeters in length at the end of the first cycle of growth. There were, however, very striking differences in the size of leaves on the new shoots. They were very large and much rumpled on the winter pruned 5-shoot trees, somewhat smaller on the 10-shoot and 20-shoot trees and about normal in size on the unrestricted trees. The differences were much less striking on the autumn pruned trees. Average values illustrating this situation are presented in Table II.

TABLE II—Influence of Season of Pruning and Number of New Shoots on Shoot Length, and Weight of Leaves of First Cycle Shoots, on Heavily Pruned Valencia Orange Trees

Number of Shoots	Period of Pruning			
	Spring		Autumn	
	Average Length Per Shoot (Cms)	Fresh Weight Per Leaf (Gms)	Average Length Per Shoot (Cms)	Fresh Weight Per Leaf (Gms)
	1938			
5	46	6.10	46	1.73
10	42	4.43	46	1.73
Unrestricted	37	1.86	30	0.95
	1939			
10	80	4.42	45	2.16
20	71	3.49	41	1.67
Unrestricted	43	1.76	39	1.08

The effect of number of new shoots on leaf size was evident to a lesser degree in second cycle shoots. Third cycle leaves were approximately normal in size in all cases.

Although some of the trees in this study were not excavated until considerably later, as indicated in Table I, we have chosen to confine our discussion to growth responses during the 12-month period following pruning. This permits comparisons as between the four

groups and reference to our earlier publications which discuss regeneration during 1- and 2-year periods following pruning (3, 4, 5).

Average values for total fresh weight of shoots on all the trees are presented in Column 9, Table I. In general, if a comparable growth period is considered, they show a progressive increase in weight per shoot associated with a decrease in number of shoots. The greater weight of individual shoots on "restricted" trees was due mainly to more lateral branches and consequently more leaves per shoot. The apparent decrease in amount of new growth of spring pruned trees in late autumn was due to a heavy drop of first cycle leaves.

The total amount of new growth produced by autumn pruned trees was approximately equal to that produced by spring pruned trees in each of the two years, although the periods and rates of growth were different (Fig. 1). This corresponds with our earlier data which

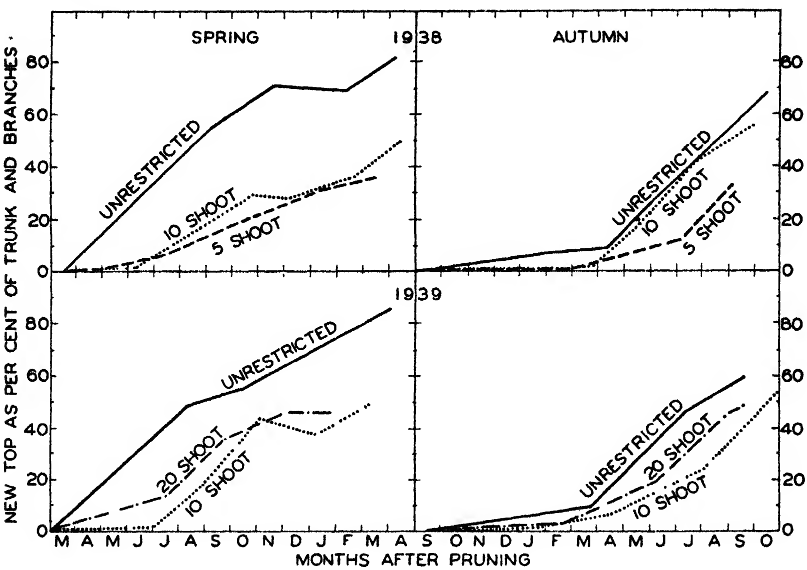

FIG. 1. Period and rate of regeneration of new top as influenced by season of pruning and number of new shoots. New growth calculated as a percentage of the weight of trunk and scaffold branches after pruning.

indicated almost identical percentages of new top growth of Valencia orange trees pruned in February, March and August (4, Table I). The data just referred to were obtained from sister trees which were planted in the orchard one year earlier than those used for the present study.

The values for total amount of new growth produced during the first year after pruning (Table I, Column 8), indicate that the "unrestricted" trees pruned in 1939 produced more new growth than did those pruned in 1938. The only other treatment represented in all four groups, the "10-shoot" trees, does not show any significant difference in the two years. The 5-shoot and 20-shoot groups each

representing only one year are valueless for comparing the growth of one year with that of the other. The unrestricted trees are too few in number and too variable in size to afford anything more than a suggestion that the 1939 pruned trees regenerated new tops more rapidly than did the trees pruned in 1938.

The trees pruned in 1939 were of course one year older than those pruned at the corresponding periods of 1938. Reference to the average values representing the weight of the whole tree or comparable parts (Table I, Columns 3, 4, 5) show an appreciable increase in size of tree in the intervals between prunings. Although no records were taken at the time of pruning, the relatively high values for total tree and above ground weights in the autumn can undoubtedly be attributed to the greater amount of leaves on the tree at that time than in the spring (2). In order to avoid this seasonal fluctuation in leaf weight and yet take into account the increase in tree size we have calculated the ratio between the weight of new growth and the weight of trunk and scaffold branch system which produced it. These values expressed as percentage are presented in Column 11 of Table I and are graphed in Fig. 1.

They indicate a rather direct correlation between size of tree at the time of pruning and the amount of new growth produced subsequent to pruning. The high values shown for the "unrestricted" trees pruned in the spring of both years may be explained, at least in part, by the fact that these trees were considerably smaller than those chosen for a restricted number of new shoots. Unpublished data, which are supported by many observations, show that a relatively greater recovery is made by a heavily pruned small tree than by a large tree similarly pruned. Although the correlation between amount of new growth and size of tree suggests that it may be an important factor in determining the amount of new growth there remains the possibility that other factors are of equal or greater importance.

We have previously reported data which apparently supported the conclusion that temperature conditions were not the dominant factor responsible for differences in growth response of citrus trees pruned in the spring of 1939 and autumn of 1940 (5, Table II). In connection with the present study we have similarly calculated, for a 1-year period following each pruning, the number of hours during which the atmospheric temperature was above 55 degrees F, which is considered to be the approximate threshold temperature for the growth of citrus (7).

The data presented in Table III indicate that the trees pruned both in the spring and autumn of 1939 were subjected to about 700 more hours of temperature above 55 degrees F than were the corresponding trees pruned in 1938.

If only growth cycle periods are taken into account, the difference in favor of the 1939 pruned trees is reduced to about 300 hours for both winter and autumn pruned trees. If this method of calculation accurately reflects the relationship between growth and temperature, we must again conclude that temperature was not an important factor in determining the amount of shoot growth produced.

TABLE III—Number of Hours of Atmospheric Temperature Above 55 Degrees F During a 12-Month Period Following Each of Four Pruning Dates

1938		1939	
Spring	Autumn	Spring	Autumn
5895	6032	6595	6689

The third factor which should be considered in relation to growth response is the amount of reserve materials available for growth at the time of pruning. Owing to conditions incident to the war, determinations of the reserve materials in the trees at the time of pruning have not been made. Earlier work on young trees (1) indicated a relatively high carbohydrate content in early spring and a low carbohydrate content in autumn. Also, unpublished microchemical studies of unpruned bearing trees of the same lot as those used for the present study show an inverse relationship between the size of crop on the tree and the starch content of bark and outer xylem of the above ground parts of the tree. The amount of fruit on the tree at the time of pruning should, if account is taken of the annual starch cycle, provide an indirect indication of the probable supply of carbohydrate available for growth.

The bearing behavior of the trees on this block is indicated by the data presented in Table IV.

TABLE IV—Average Yield of Valencia Orange Trees in Pruning Plot 1936–1941 Inclusive

Pounds per tree

1936	1937	1938	1939	1940	1941
210	94	310	137	368	215

That the trees in this block were bearing alternately large and small crops is clearly evident from these data. It will be observed that 1938 was a big crop year and 1939 a small crop year. We may assume then that carbohydrate storage was considerably higher in the spring of 1939 than in the spring of 1938. That this might in part have been responsible for more total new growth is suggested by the larger shoots produced during the spring growth cycle of 1939 than during the corresponding period of 1938 (Table III). Temperature summations were nearly the same for these two periods; 1298 and 1200 hours respectively of temperature above 55 degrees F.

The slower rate and smaller amount of new growth made by first cycle shoots on autumn pruned than on spring pruned trees in both years may also be due, in part, to a smaller carbohydrate supply. However, our observations of the growth response suggest the possibility that some internal factor associated with cyclic growth may be more responsible for the weak and sparse new growth on autumn pruned trees than the relatively low carbohydrate content of the tissues at the time of pruning. Temperature records show that favorable

conditions for growth usually occur in the autumn for about three months after the period when these trees were pruned.

Reference has been made to the greater amount of new growth made, in both years, by the "unrestricted" spring pruned trees and attention called to the possibility that this may in part be apparent rather than real due to the smaller size of these trees. That these trees did actually produce considerably more new growth than those of any other group is shown by the values for total fresh weight presented in Column 8 of Table I. We believe that the rapid development of a large leaf surface, which provided photo-synthetic materials for further growth was the most important factor in this case.

Our observations of the growth responses of this group of 64 trees, most of which appear to be supported by the data, suggest that the amount of new shoot growth made subsequent to pruning is determined in the initial stages by the supply of materials available for growth and by an unknown factor associated with cyclic growth. Subsequent to this initial period of growth, which determines the amount of leaf surface developed, the amount of new shoot growth seems to be determined by the products of that leaf surface. (Column 13 Table I; Calculated as in (3)).

Chandler (6) has called attention to the difference in response to severe pruning of deciduous and some evergreen species. The orange tree appears to belong to that group of evergreens which rejuvenate new tops comparatively slowly, especially during the first year following pruning. In the spring of 1938 when the first group of orange trees was pruned, groups of avocado and almond trees were similarly treated. The almond trees produced relatively much more new shoot growth during the first year than did the orange and the total amount of growth produced was little affected by the number of new shoots. New shoot growth on the avocado trees was quite irregular due to the failure of many buds in the old bark to grow. Those buds which did grow produced shoots intermediate in relative size between those of the orange and the almond. Further work designed to provide more information regarding this difference in response to pruning of evergreens and between evergreen and deciduous fruit species is in progress.

Summary and Conclusions

A study of the influence of number of new shoots and time of pruning on the rate of top regeneration of heavily pruned Valencia orange trees suggests the following conclusions:

1. Trees with an unrestricted number of new shoots regenerate new tops more rapidly than do those with a smaller number of new shoots. The differences are more pronounced in spring pruned than in autumn pruned trees.

2. The rate and amount of regeneration seem to be influenced in the initial stages by the supply of materials available for growth at the time of pruning and by some unknown factor associated with cyclic growth. Later the size of the leaf surface developed appears to assume the dominant role.

3. In this study temperature seems not to have been either a dominant or a limiting factor.

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The Effect on Pecan Rosette From Applications of Zinc Sulfate, Manure, and Sulfur on Heavy-Textured Alkaline Soils

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A few trials of applications of a combination of manure, sulfur, and zinc sulfate in combination with other treatments for the cure of pecan rosette were made on Johnston fine sandy loam soil in Denton County, Texas, and on Miller loam in Bossier Parish, Louisiana, in the early spring of 1940 (1). Because of the favorable results obtained in these two trials, more extensive tests were started on Pledger clay soil in Brazoria County, Texas, in the spring of 1941 and on Catalpa Clay in Bexar County, Texas, in the spring of 1942.

On the Pledger clay applications of zinc sulfate by itself at rates of 25, 50 and 75 pounds per tree, broadcast and plowed under, had been made in the spring of 1940. Little or no improvement in the rosette condition of the treated trees was noted during 1940.

On the Catalpa clay zinc sulfate had been applied to pecan trees in 1934 at rates of 20, 40, 60, 80, and 100 pounds per square foot of cross-sectional area of the tree trunk in trenches around the tree trunk and also broadcast under the spread of the branches. Sulfur was also applied broadcast by itself and in combination with zinc sulfate. The broadcast applications were plowed under. No beneficial effect on the rosette condition of the treated trees was ever noted, although they were observed for a period of several years.

The zinc-fixing power (2) of the 0 to 6 inch horizon of the Pledger clay was found to be 4800 pounds of zinc per acre, and for the same horizon of Catalpa clay it was 60,000 pounds per acre, as compared with 80 pounds for the same acre-horizon of an Orangeburg fine sandy loam from Caddo Parish, Louisiana. The amounts of zinc fixed were obtained by washing soil that had been in a zinc sulfate solution with distilled water until the washings gave no test for sulfates. The zinc was then determined in the washed soil.

Experimental

In the experiment on the Pledger clay the treatments used were: manure, sulfur, and zinc sulfate; sulfur and zinc sulfate; manure and sulfur; zinc sulfate; and sulfur. Zinc sulfate was used at two levels, 50 and 75 pounds, in all treatments requiring this material. One cubic yard of sheep manure and 50 pounds of sulfur were composted for each of 10 trees used in the experiment. All the materials used, either by themselves or in combination, were spread broadcast in an area extending from the tree trunk to a distance slightly beyond the spread of the branches and then turned under with a turning plow.

The trees used in this experiment were selected in October 1940 and each tree was scored as to the amount of the tree top affected by the rosette condition. The rosette condition was recorded as being

of four degrees designated by 1R, 2R, 3R, and 4R, representing the involvement of as many fourths of the tree. Single-tree plots were used and each treatment was replicated five times. The rosette condition of the trees, treatments used, and other data are given in Table I.

TABLE I—AFFECTS OF ZINC SULFATE, MANURE, AND SULFUR IN VARIOUS COMBINATIONS APPLIED BROADCAST ON PLEDGER CLAY SOIL IN THE TREATMENT OF PECAN TREES FOR ROSETTE

Treatment Per Tree, Spring of 1941			Rosette Condition of Trees*	
Zinc Sulfate (Pounds)	Manure (Yards)	Sulphur (Pounds)	When Treated Oct 30, 1940	After Treatment June 22, 1943
50	1	50	3R	NR
50	1	50	1R	NR
50	1	50	3R	NR
75	1	50	3R	NR
75	1	50	2R	NR
50	-	50	2R	NR
50	-	50	1R	1R
50	-	50	2R	Died
75	-	50	2R	NR
75	-	50	3R	NR
50	-	—	2R	NR
50	-	—	1R	Trace
50	-	—	2R	NR
75	-	—	3R	1R
75	-	—	3R	NR
—	-	50	2R	1R
—	-	50	2R	1R
—	-	50	3R	1R
—	-	50	1R	1R
—	-	50	2R	1R
—	1	50	1R	1R
—	1	50	3R	1R
—	1	50	2R	3R
—	1	50	2R	1R
—	1	50	2R	3R
Check, no treatment			2R	2R
Check, no treatment			2R	1R
Check, no treatment			1R	2R
Check, no treatment			3R	2R
Check, no treatment			2R	1R

*The rosette condition was scored on the basis of four degrees denoted by 1R, 2R, 3R, 4R representing the involvement of as many fourths of the tree. NR indicates no rosette symptoms.

The results show that all trees that received the zinc sulfate, manure, and sulfur combination had completely recovered from the rosette condition when observed in June 1943. The sulfur and zinc sulfate treatment was the next most effective, followed closely by zinc sulfate alone. Sulfur by itself resulted in a lessening of the rosette condition in all trees, but not in complete recovery. The sulfur and manure treatment was no better than the check treatment, only two trees in each of these treatments showing any improvement. There was little or no apparent difference in effectiveness of 50-pound and 75-pound dosages of zinc sulfate in this test.

The trees in the orchard on the Catalpa clay soil used in this experiment were in a severe rosette condition in 1934 when they were all scored as 4R. Since no improvement in the rosette condition had oc-

curred in the intervening years, they were again scored as 4R in the spring of 1942 when the experiment was started. Single-tree plots were replicated three times, except in one case where 200 pounds of zinc sulfate plus the manure and sulfur were applied to only one tree. In this experiment dairy yard-manure having considerable soil mixed with it was used. For each tree in the experiment, one-fifth cubic yard of manure was composted with 50 pounds of sulfur on February 6, 1942. The compost pile was fully moistened with water and allowed to ferment. On February 27, 1942, zinc sulfate at rates of 50, 85, 100, and 200 pounds per tree was mixed with the compost. To one-half of the number of trees in the experiment the manure, sulfur, and zinc sulfate mixture was applied broadcast underneath the trees and plowed under, and to the remaining trees it was applied in holes two feet deep and eight inches in diameter made in the soil at intervals of 2 feet apart in a circle around the tree, 8 feet from the tree trunk. The treatments used and the results obtained are given in Table II.

TABLE II—Effects of Varying Amounts of Zinc Sulfate Mixed with a Compost Consisting of $^{1}/_{5}$ Cubic Yard of Manure and 50 Pounds of Sulfur per Tree Applied Broadcast or in Holes in the Soil, for the Treatment of Badly Rosetted Pecan Trees Growing in Catalpa Clay Soil

Treatment Feb 27, 1942	Rosette Condition of the Trees		
		Condition June 21, 1943	
Zinc Sulfate (Pounds per Tree, Mixed with Manure-Sulfur Compost)	Condition Feb 27, 1942 At Time of Treatment	Method A Applied Broadcast and Plowed in	Method B Applied in Holes
50	4R	2R	2R
50	4R	1R	NR
50	4R	NR	Trace
75	4R	Trace	1R
75	4R	2R	NR
75	4R	NR	Trace
100	4R	NR	4R
100	4R	NR	NR
100	4R	NR	NR
200	4R	NR	NR

There was an improvement in the rosette condition of all but one of the trees. The best results were obtained with the heavier applications of zinc sulfate. All the trees that received 100- or 200-pound applications of zinc sulfate in combination with manure and sulfur were free of the rosette condition on June 21, 1943, 16 months after the treatment was applied, except that one of the trees to which the compost and zinc sulfate was applied in holes showed no improvement. Some of the trees that received less than 100 pounds of zinc sulfate were free of the rosette condition and some were not, although there was marked improvement in their condition as compared with what it was prior to treatment.

In general, the data indicates that the broadcast application of the manure-sulfur compost and zinc sulfate was somewhat more effective

in bringing about the recovery of the trees from the rosette condition than was the application made in holes in the soil.

Samples of the sulfur-manure compost were taken from six of the compost piles February 6, the day the zinc sulfate was mixed with them and applications made to the soil. The range in reaction of the six samples was from pH 5.7 to 6.2. Samples were taken on September 9, 1942, from one of each kind of treatment. The data are given in Table III. Most of the data indicate clearly that bacterial activity converting the sulfur to sulfates must have continued after the zinc sulfate was added to the compost and the mixture applied to the soil. Some of the pH values are very low especially those from the 100-pound application of zinc sulfate in holes in the ground where one reaction of pH 1.7 was recorded. With the 200-pound application of zinc sulfate in holes the pH value did not change appreciably. The zinc sulfate may have hindered bacterial activity in this instance. In the laboratory the six samples of sulfur-manure compost taken from the compost piles and kept moist in jars attained an average reaction of pH 1.16 during the same period. Some difficulty was experienced in obtaining samples of compost free from contamination with soil. Inconsistencies in the trend of pH values can be attributed in part to incorporation of soil with some of the compost samples.

TABLE III—HYDROGEN-ION DETERMINATIONS FROM EIGHT LOCATIONS AND 6½ MONTHS AFTER APPLICATION

Treatment			Depth of Sampling (Inches)	pH
Zinc Sulfate (Pounds)	Manure (Yards)	Sulfur (Pounds)		
		Compost Applied in Holes		
50	1/5	50	0-6	4.1
			6-12	3.7
			12 24	3 7
75	1/5	50	0-6	5 9
			6-12	5.7
			12-24	3.8
100	1/5	50	0-6	2.6
			6-12	1.7
			12-24	4.6
200	1/5	50	0 6	7.0
			6-12	6.6
			12 24	6 4
		Compost Broadcast Plowed Under		
50	1/5	50	In compost horizon	5.6
75	1/5	50	In compost horizon	6.4
100	1/5	50	In compost horizon	5 7
200	1/5	50	In compost horizon	4.8

DISCUSSION

In the native pecan territory it is common knowledge that the trees in natural stands frequently develop rosette when brought under cultivation. Such trees have been known to rosette following the removal of the underbrush and the thinning of the stands of native trees, even though no cultivation was practiced. Hibbard (3) found an accumulation of zinc in the humus layer of undisturbed soil. Under natural

conditions pecan tree roots come to the surface of the soil and grow freely in the decaying leaves that have accumulated there, in which there is a comparatively high concentration of available zinc. When the soil is plowed the tree roots are deprived of this horizon of available zinc by the destruction of some organic matter and the mixing of the residue with soil having an alkaline pH. Likewise, when a pecan grove is thinned the burning operations which go with that operation frequently destroy much of this organic matter on the surface of the soil. These thinning operations also let in the sun, causing the drying out of the surface soil, which results in the killing of the tender feeding roots. The end result of thinning the stand of native trees is similar to that of plowing, in that the trees are deprived to a considerable extent of their soil horizon of available zinc. The favorable results obtained with the treatments reported here are attributed to supplying a medium high in availability of practically all essential elements, but especially high in available zinc.

That the agencies which operate to convert sulfur to sulfates can continue their activity even with heavy applications of zinc sulfate is a distinct advantage in handling this treatment. If the conversion of sulfur to sulfates were stepped up by the addition of zinc sulfate, this material could not be added until the compost of sulfur and manure had been given sufficient time to reach the desired point. In such case, the manure-sulfur compost would most likely need to be made away from the orchard and kept in a moist condition over a period of several months with protection from leaching by rains, which would complicate the treatment considerably.

The Pledger clay soil used in this experiment had an original pH of 7.4, a clay content of 56 per cent, and a calcium carbonate content of 1.70 per cent. The Catalpa clay soil had an original pH of 7.8, a clay content of 61 per cent, and a calcium carbonate content of 21.4 per cent. The high clay content in each soil causes great resistance to any change in soil reaction; both soils, but particularly the Catalpa clay soil, contained a high calcium carbonate as well as clay content. On both of these soils the mixture of zinc sulfate, manure, and sulfur applied broadcast and turned under was highly effective in either improving or, in the cases where large amounts of zinc sulfate were used, in clearing up the rosette condition. Considering the high pH, the large amounts of clay, the large amount of calcium carbonate, and high fixing power of these soils for zinc, especially that of the Catalpa clay, and the prompt recovery of the pecan trees from rosette through the use of manure and sulfur composted together to which was added large amounts of zinc sulfate, it is believed that rosetted pecan trees on almost any soil on which they are grown should respond satisfactorily to this treatment.

To lower the soil reaction appreciably or to saturate the fixing power of such soils as the Pledger clay or Catalpa clay with zinc sulfate alone, so as to make zinc available to the trees, would be prohibitive in cost even in a six-inch horizon over an area limited to the spread of the branches of a pecan tree. Although the quantities of manure, sulfur, and zinc sulfate mixture found to be required to effect

control of rosette in one tree are large and costly, their use is very practical. Large trees so treated have paid for all costs in a single crop.

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Cambium Temperatures of Peach and Apple Trees in Winter

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THE importance of temperature variations on opposite sides of trees during winter has long been emphasized (1, 3, 5, 6, 7). The results of these experiments show a great deal of variation which is probably due in some cases to instruments not being constructed for, nor adapted to the job for which they were used.

In order to study the effects of winter injury on fruit trees it was considered necessary to find an accurate method of measuring tree temperatures. Although the potentiometer and thermocouple have been in general use for many years, little, if any, consideration has been given to the effect of thermal conduction along leadwires on temperatures at junctions imbedded in plant tissue. The writer (2) found that such conduction was an important factor when No. 30 copper-constantan thermocouples were used.

Experiments were planned and set up for the purpose of obtaining a record of winter temperatures in the cambium of peach and apple trees, and in their roots and the soil in which they were growing, under different weather conditions. This paper, the first of a series, will deal only with cambium temperatures of the trunks of these trees.

EXPERIMENTAL PLAN

Two 17-year-old Northern Spy apple trees and two peach trees (Valiant and Carman varieties) were selected for the trials. They were located in adjoining parallel rows of peach and apple experimental plots at the horticultural farm. Both orchards are on a northeast slope of about 15 degrees.

Girths of the two peach trees measured at 1 foot above ground were 22¾ and 18½ inches, respectively, for trees No. 1 and 2. The apple trees, however, were much larger, No. 3 and 4 being 34½ and 38 inches in circumference.

All thermocouples were installed on August 28, 1943, while bark was still slipping. Those in or very close to the cambium were pushed

TABLE I—THE LOCATION OF THERMOCOUPLES AT EACH TREE USED IN THE COURSE OF THESE STUDIES

No. of Thermocouple	Where Installed	Position in Respect to Tree
1	Cambium	West side of tree—1 foot above ground
2	Cambium	South side of tree—1 foot above ground
3	Cambium	East side of tree—1 foot above ground
4	Cambium	North side of tree—1 foot above ground
5	Cambium	Top of horizontal limb 6 feet high
6	Cambium	Top of horizontal root upper side of which was 4 inches below soil surface
7	Soil	Along side of No. 6 on west side of tree
8	Cambium	4 inches above soil on west side of tree
9	Air	1 foot above soil, 2 feet from tree trunk, suspended from limb on west side of tree

into holes made parallel to the length of the trunk or limb by inserting a 1.5 mm hard, sharpened steel wire a distance of 3 inches. Grafting wax was used to seal the small opening where wires emerged from the tree. Leadwires extended to a heated shed located at a central point. Here they were attached to a switchboard which made it possible to record all temperatures at each tree within 2.5 minutes by means of a portable potentiometer indicator manufactured by Leeds and Northrup Company. This instrument read directly in degrees Fahrenheit and was equipped with automatic reference junction compensator. Thermocouples were located as indicated in Table I.

Data on Peach Tree Temperatures

It is worthy of note that data collected over a period of 3 months show that temperatures on similar days were almost identical. On clear, calm days during the period from December to March the peak temperature on the south side of peach trees was reached at some time between 12:00 M. and 2:00 p. m. depending on the weather. Cambium temperatures of 60 degrees F or higher were recorded on 18 different days of the 90 during which the instrument was operated. On five days cambium temperatures on the south sides of peach tree trunks reached 80 degrees F or more. On most of these days air temperature was at or below 32 degrees F. The highest recorded was on March 6 when at 12:00 M. It reached 86 degrees F at which time the air temperature was 31.5 degrees F.

A cold north wind seemed to have but little influence on temperatures in the cambium on the south sides of the trunks on clear days of bright sunshine. Peak temperatures on those days were as high or higher than they were in the same position on several equally cold days when no wind was blowing. A hazy atmosphere or wind blowing against the positions where the thermocouples were located both greatly reduced the high temperatures they reached on any given day.

During cloudy days and at night cambium temperatures on all sides of the trees closely approached those of air by 10:30 p. m.

The trunk of peach tree No. 1 was painted white on January 19 and

TABLE II—Highest Cambium Temperatures Reached on the Four Sides of Two Peach Tree Trunks on January 13 When Both Were Unpainted, and on January 31 After the Trunk of Tree No. 1 Was Painted White

Tree No.	Side of Trunk	Highest Temperature Reached (Degrees F)	
		January 13 Unpainted	January 31 No. 1 Painted White
1	South	65.75	34.0
2	South	69.0	82.5
1	West	35.5	28.5
2	West	43.0	58.0
1	East	30.25	27.5
2	East	34.0	35.0
1	North	25.5	26.5
2	North	31.5	31.5
Air Temperature		31.75	29.75

was allowed to dry for 12 days before making temperature comparisons.

The extent to which the temperature of the cambium on all four sides of the trunk was affected by painting is summarized in Table II.

Data on Apple Tree Temperatures

An examination of temperatures in apple trees taken on the same days as the preceding records of peach trees reveals the same general pattern. However, if the sun continued to shine all day peak temperatures were recorded on the south and west sides of apple trees at from 3:00 to 5:00 p. m. The highest obtained was on February 21 when it reached 61.75 degrees F at 5:00 p. m. at which time the temperature of the air was 40 degrees F.

The effect of white paint on the cambium temperatures in one of the apple tree trunks is indicated in Table III.

TABLE III—Highest Temperatures Reached in the Cambium of Two Apple Tree Trunks on January 13 When Both Were Unpainted and Again on January 31 After Three-fourths of the Trunk of Tree No. 4 Had Been Painted White. The North 1 Quarter of the Trunk Was Left Unpainted

Tree No.	Side of Trunk	Highest Temperature Reached (Degrees F)	
		January 13	January 31
3	South	53.5	60 75
4	South	50.5	36.5 painted
3	West	30.25	31.0
4	West	29.5	29 0 painted
3	East	43 5	35 0
4	East	44.5	34.25 painted
3	North	25.0	29.0
4	North	28.75	31.5
Air Temperature		31.75	29.75

Discussion

One point is particularly outstanding under the conditions of this experiment. In spite of the fact that a much smaller girth (and consequently decreased area) was exposed to direct rays of the sun at any one time, the cambium on the south sides of unpainted peach tree trunks reached much higher temperatures than it did on the same side of apple trees during the same period. This involves problems of the smoothness and thickness of bark, its color and texture, the importance of which has long been emphasized by Harvey (4) and others.

Steinmetz and Hilborn (8) in freezing tests on apple wood have shown that cambium tissue seems to be the most hardy of all living cells in the parts of that tree above ground. This is borne out in examination of old orchards which have recovered from severe cases of winter injury. It might be taken as an indication that high temperatures in the region of the cambium in winter are insignificant. However, in recent experiments on maple trees (9) it was found that temperatures reached in the centers of those trees were largely

determined by the height to which the temperature of the cambium went earlier in the day. It was also determined that when the temperature of a sufficient amount of xylem in maple trees reached 35 degrees to 40 degrees F, it played a significant part in the movement of sap through the trunk of the tree, especially during periods when air temperature dropped below freezing.

Whether or not this condition occurs in peach and apple trees will need to be determined.

Summary and Conclusions

1. On clear days in winter when no wind is blowing, temperatures of the cambium on the south side of peach tree trunks can frequently rise to 60 degrees or 80 degrees F or higher.
2. On similar days temperatures at the same position in 20-year-old apple trees reaches 60 degrees F or higher.
3. Except during periods of falling temperature cambium on the north sides of both peach and apple tree trunks is seldom as warm as air.
4. Differences in temperature on the north and south sides of unpainted tree trunks were found to be as high as 50 degrees to 55 degrees F in peach, and from 30 degrees to 35 degrees F in apple under the conditions of this experiment.
5. The effect of painting peach and apple tree trunks white to reduce temperature variations between the north and south sides is most pronounced on clear days when no wind is blowing.
6. During the course of these studies temperatures in the cambium on the south sides of peach and apple tree trunks which were painted white were at no time more than 10 degrees F warmer than air.
7. Cambiums of both painted and unpainted trees reached nearly the same temperature as air during cloudy periods or at night.
8. The value of painting trees white to prevent extreme fluctuation of temperature in them during winter has not been determined.

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Preliminary Investigations of the Cold Resistance of Peach Fruit Buds at the Pink Bud Stages of Development

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THE development by Meader, Davidson, and Blake (1) of the New Jersey controlled freezing method for testing the cold resistance of dormant peach fruit buds has made it possible to test the cold resistance of peach buds at various other stages of their development.

Varietal studies at the New Jersey Station over a period of many years has revealed that at the pink bud stage of development, some varieties are hardier than others. Dwarf Blood, for example, is hardier than Elberta.

It has further been observed that the fruit buds of some species and varieties that are relatively tender to low temperatures while dormant in early winter are relatively hardy during the pink bud and full bloom stages in early spring. *Prunus kansuensis* buds compared with those of common varieties at New Brunswick are only moderately hardy while dormant, but are distinctly hardy when in pink bud or in full bloom. This is of particular importance in peach regions where the minimum winter temperatures seldom fall below −5 degrees F, for there the primary danger of injury to peach buds from low temperatures occurs in spring.

The belief is rather general that as a peach bud advances in development, it becomes increasingly susceptible to injury by cold, and that late blooming varieties should be selected for sites where late spring frosts are likely to prevail.

Observations of varieties at the New Jersey Station revealed many years ago that a late blooming variety was sometimes more susceptible to cold injury during the dormant season and at blooming time, than some which bloomed earlier. Scott and Cullinan (2) report similar observations at Beltsville.

STAGES OF BUD DEVELOPMENT

In order to test and discuss the cold resistance of developing buds of the peach in early spring, it is necessary to adopt some form of classification of the various stages of bud development. The following arrangement has been adopted in New Jersey:

1. Beginning of Silver Bud:—When the dormant fruit buds of the peach start to swell, the outer brown scales separate until the lighter color and pubescence upon portions of the inner bud scales are exposed. This may occur first near the tip of the bud but often extends well toward the base in the form of a narrow slit. This gives the bud, especially the tip, a lighter color.

The fruit buds of *Prunus davidiana* trees as grown at New Brunswick, New Jersey, vary from those of common American varieties of peaches. When the buds first start to swell, the sepals of the calyx are often exposed and have comparatively little pubescence. Often the

sepals of the calyx may separate at the beginning of the silver bud exposing the pink of the corolla. It is, therefore, difficult to classify the early developing stages of the buds of such a peach.

2. *Advanced Silver Bud:*—There is a stage in bud development when a maximum of light colored pubescence on the sepals and calyx shows. This might be called the advanced silver bud. The light colored tips of the buds can be seen as far away from the tree as the details of bud form can be observed.

3. *Calyx Green:*—As bud development continues, the sepals and calyx enlarge, the light colored pubescence wears away somewhat, and the color of the calyx becomes a dull greenish red upon varieties possessing red in the skin color of the ripe fruits. The calyx and sepals of pure white or pure yellow skinned varieties and with no red upon the twigs are usually green with no red. Types of *Prunus davidiana, P. kansuensis*, and red leafed peaches present buds at this stage which are distinctly reddish rather than green in color. However, this color is a dull red, lightened in appearance by some pubescence and quite distinct from the color of the corolla which is exposed later.

4. *Beginning of Pink Bud:*—Tips of corollas of most advanced buds slightly exposed.

5. *Early Pink Bud:*—Tip of corolla of most buds exposed enough to be readily seen, or about 1/4 to 3/8 of an inch.

6. *Medium Pink Bud:*—Corolla of most buds about one-half developed.

7. *Advanced Pink Bud:*—Corolla well developed. Petals at stage of expanding.

All of these stages of development are so narrow that buds may quickly pass from one to another when temperatures above 65 degrees F are experienced. In the case of flowers of the non-showy petal type, the stigma is sometimes exposed beyond the petals at the medium pink bud stage, and especially at the advanced pink bud stage.

To test the relative hardiness of buds in the same exterior growth conditions but with the pistil tip or stigma exposed, as compared to buds with the stigma not showing, two lots of buds of Camelliaflore were selected and exposed in the freezer to 8 degrees F. The results were as follows:

1. Buds with stigmas not showing — 50.6 per cent alive.
2. Buds with stigmas showing — 31.9 per cent alive.

It should not be concluded that the external appearance of a peach bud is always a true measure of its state of internal development. Peach buds at the advanced pink stage exposed for several days at a rather uniform temperature of about 40 to 42 degrees F made no observable growth or change as far as the corolla was concerned but the pistils did elongate inside the exposed corolla and the ovary may have made some growth also. Therefore, although a bud in the so-called early pink stage on April 22 may appear to be in the same stage as on April 20 or 2 days earlier, it may actually have undergone a change in internal composition and development of the reproductive organs. Such a bud might be expected to have become definitely reduced in hardiness.

Comparative Resistance of the Buds to the Various Low Temperatures

In the spring of 1942, plans were made to gain information as to the relative hardiness of peach fruit buds after they had developed beyond the advanved silver bud stage. For the first test, buds of Cumberland and Greensboro at the early pink bud stage, and of Dwarf Blood, Mexican Honey (P. I. 32373), and Elberta at the medium pink bud stage were selected. They were obtained on April 16 when the maximum day temperature was 46 degrees F. The samples were placed in the temperature controlled freezer at 4:30 p. m., at an initial temperature of 62 degrees F. The temperature was gradually lowered to 20 degrees F at 8:30 a. m. on April 17, at which time the first set of samples was removed. The rate of drop in temperature averaged 2.23 degrees per hour. By 10:30 a. m., the temperature surrounding the buds had dropped to 15 degrees F, and a second set of samples was removed. A third lot of samples was left in the freezer until 5:30 p. m., by which time they had been exposed to a temperature of 9 degrees F. The results of this test are given in Table I.

TABLE I—Comparative Resistance of the Fruit Buds of Five Varieties of Peach in the Early or Medium Pink Bud Stages to Temperatures of 20, 15, and 9 Degrees F on April 16, 1942

Variety and Stage	Temperature of Freezer (Degrees F)	Per Cent Alive
Early Pink Bud		
Cumberland	20	88
Cumberland	15	59
Cumberland	9	62
Greensboro	20	78
Greensboro	9	43
Medium Pink Bud		
Dwarf Blood	20	96
Dwarf Blood	15	92
Dwarf Blood	9	88
Mexican Honey (P. I. 32373)	20	94
Mexican Honey (P. I. 32373)	15	71
Mexican Honey (P. I. 32373)	9	22
Elberta	20	65
Elberta	9	9

The percentage of injured buds of Cumberland, Dwarf Blood, Greensboro, and Mexican Honey at 20 degrees F did not exceed 22 per cent in the case of any one variety. This is not sufficient to reduce the crop in the case of such varieties. In fact, the trees often require hand thinning of the green fruits even when as many as 40 per cent of the buds are killed of such prolific bud setting varieties. Elberta experienced somewhat more injury than the other four varieties but still not enough to reduce the crop of fruit.

The buds of Dwarf Blood experienced very little more injury at 15 degrees than at 20 degrees F and the injury was not serious enough with Cumberland or Mexican Honey to reduce the crop of fruit.

At 9 degrees F the injury to the Elberta buds in a medium pink bud stage was severe. Mexican Honey buds at a similar stage experienced less, but still considerable, injury. Greensboro and Cumberland

buds were moderately resistant, and Dwarf Blood was outstandingly so.

A second test similar to the first was made with buds of Raritan Rose on April 20, on which date they had reached the advanced pink bud stage of development.

One lot of buds was taken out of the freezer at 20 degrees F, a second lot at 15 degrees, and the third at 10 degrees. The results were 77, 45, and 23 per cent of the buds alive respectively. It was apparent from the two tests that under the out-of-door conditions which prevailed at New Brunswick in April, 1942, and with the freezing method practiced, buds of peaches in the pink bud stages would require a slow freeze to as low as 10 degrees F in order to obtain enough bud killing for worthwhile hardiness comparisons.

The Relative Bud Development and Hardiness of Sixteen Varieties of Peaches

By April 20, 1942, the buds at New Brunswick were well developed beyond the so-called dormant stage. In fact, Dwarf Blood had developed to the first bloom stage, and so could not be included in this test. An attempt was made to obtain representative samples of buds of different varieties which would cover the entire range of bud development from the sepal and calyx well-exposed stage to the advanced pink bud stage. In order to do this, it was found necessary to include some unnamed New Jersey seedlings of known parentage.

The maximum outside day temperature on April 20, when the buds were cut, was 58 degrees F. The buds were put into the freezer at 5:00 p. m., and removed at 4:30 a. m. on April 21, when the temperature had been lowered to 10 degrees F. The results are given in Table II.

The most striking result of this last freezing test was that the buds of the very late blooming Early Heath, which showed no pink color on April 20, were more sensitive to a temperature of 10 degrees F than even the advanced pink buds of Hiley and Summercrest, which were at the point of bursting into bloom. This result conforms with the experience of the writer that some of the very late blooming varieties of peaches are relatively vegetative in type, and thus are likely to be more susceptible to injury from low temperatures in early spring than a more fruitful early blooming variety such as Dwarf Blood. This is in agreement with the observations of Scott and Cullinan (2).

No attempt has been made to classify the sixteen varieties used in this test in order of relative hardiness. The bud samples are rather small and more than one test is necessary for accurate and final varietal ratings. There is no question, however, about the relative tenderness of the buds of Early Heath as compared to most of the other fifteen varieties. There is little doubt that N. J. 10336 was hardier than N. J. 110936, and that N. J. 5536 was hardier than Aicken's Cling.

Krummel October passed through one dormant season at New Brunswick with 80 per cent of its buds alive, while Eclipse had only 15 per cent remaining alive. The weather was cold and unfavorable

TABLE II—RESULTS OF EXPOSING DEVELOPING BUDS OF THE PEACH TO A TEMPERATURE OF 10 DEGREES F ON APRIL 20, 1942

Variety and Stage	Total Buds	Per Cent Alive
Calyx Green		
Early Heath	176	9
Beginning Pink Bud		
N. J. 10336	160	61
Fair's Beauty	214	53
N. J. Red A	270	22
N. J. 108536	143	14
N. J. 110936	165	3
Early Pink Bud		
N. J. 33936	244	54
N. J. 50536	120	10
Medium Pink Bud		
N. J. 37 B. G.	180	26
Belle	148	20
Advanced Pink Bud		
N. J. 5536	188	42
Hiley	145	23
P. I. 43051	132	21
Summercrest	211	20
Hardee	124	16
Aicken's Cling	199	3

during the pink bud stages of development in April of that year. Eclipse finally produced a crop of fruit, whereas Krummel bore only an occasional specimen. There was no way of determining at that time the relative difference in the degree of cold resistance of the buds of the two varieties when passing through the pink bud stages of development.

The observations of Joley and Bradford (3) of the response of the opening fruit buds of North Caucasus peaches to low temperatures suggests the desirability of further investigations of the hardiness of different types, varieties, and species of peaches at different stages of development.

The results of these tests are of considerable practical significance both to breeders and to commercial growers since slight differences in temperature at blooming time often may mean the difference between a fair crop of peaches and no crop.

This paper is intentionally brief and no attempt has been made to draw general conclusions since it is obvious from the results and the literature cited that many variable factors are concerned in the hardiness of the fruit buds of the peach at different stages of development.

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A New Material for Blossom Thinning, to Serve as a Sticker, and to Reduce Transpiration

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Blossom Thinning

For well over a decade efforts have been made to find or develop some material which when applied to trees in bloom will reduce their set of fruit and reduce the labor of hand thinning. Many materials have been tried, both experimentally and in commercial plantings. From the standpoint of destroying flowers, or their parts, and reducing the subsequent set of fruit several of the more caustic materials commonly used in the control of certain insect pests have proved most effective. Among the more important of these are some of the heavy mineral oils and several of the dinitro-cresylic and dinitrophenolic compounds. Though effective in killing flowers and reducing set of fruit they have been rather generally unsatisfactory in two respects, namely, (a) The results attending their use vary greatly from season to season, from orchard to orchard, from variety to variety, and even from tree to tree. Apparently differences in tree vigor and in weather, as well as variety, cause wide variations in the susceptibility of the several flower tissues to the caustic action of the materials. (b) Often there is serious injury to the leaves and even the bark and woody tissues of the spurs. The result is that investigators hesitate to recommend their general use by fruit growers, and some growers who do use them on a commercial scale are enthusiastic about them while others condemn them. Obviously, if thinning at blossoming time is to become a labor-saving method of reducing total fruit thinning costs, some new materials or new techniques must be developed that are safe as well as effective. This is a brief report on a new material for this purpose.

In the fall of 1938, the Michigan Experiment Station began work on the development of a material that can be applied as a spray during the active growing season, that is non-toxic to foliage but that will reduce transpiration. In general terms the objective was to develop a substitute for irrigation to combat drought chemically. Numerous difficulties were encountered. It was soon evident, however, that of the materials being tried some of the vegetable oils were most promising. After several years of experimentation several different combinations of vegetable oils, paraffin wax, bentonite and an emulsifying agent have been perfected that apparently possess in rather marked degree some of the characteristics sought.

One of these oil-wax emulsions in 1 and 5 per cent concentrations was used experimentally on Duchess apple trees at Grand Rapids, Michigan, when they were in full bloom in May, 1944. The trees were 25 years old, in good vigor, and bore a heavy crop of blossoms. Conditions were favorable for pollination and fruit setting. There was no evidence of any injury to any of the vegetative tissues. No spurs were killed and there was no marginal or other burning of the edges or tips

of the small basal spur leaves. Indeed those leaves remained green and apparently effective as photosynthetic organs throughout the season. Influence on setting of fruit was measured by determining the numbers and percentages of spurs bearing single fruits or clusters of two, three, or four fruits at harvest. On the check trees 58 per cent of the bearing spurs carried one fruit only, 34 per cent bore two fruits each, 8 per cent bore clusters of three or four each. On the trees sprayed with a 1 per cent oil-wax emulsion, 75 per cent of the bearing clusters carried one fruit each, 22 per cent two each, and 6 per cent three each. The figures for the trees sprayed with a 5 per cent concentration of the emulsion were almost identical with those sprayed with the 1 per cent concentration. The crops ranged from 1500 to 2600 fruits per tree. The reduction in set was not drastic but it was significant and enough to reduce substantially the amount of hand thinning required.

The tests reported here were limited in scope. They do not warrant any general recommendation for large scale commercial use. They do warrant extensive experimental trials with different varieties and under different environmental conditions. It is expected that this emulsion will be available in the spring of 1945 in sufficient quantities for such trials.

Other Uses of the Oil-Wax Emulsion

To Reduce Transpiration:—It was stated that the original objective in connection with these oil-wax emulsions was to develop a material which when sprayed on plants would reduce transpiration and thus in some measure serve as a substitute for irrigation. Extensive laboratory and greenhouse tests under controlled conditions indicate reductions of from 20 to 60 per cent in transpiration rate, depending on kind of plant, conditions of environment and concentration of the emulsion, with no apparent injurious effect on the foliage when suitable dilutions are employed. Field trials on which data are available at this time are limited to treatments of bearing Montmorency cherry trees in Michigan this past season.

One of these oil-wax emulsions (a different one from that used in the blossom thinning experiments) was applied to trees 7 and 8 years old and producing crops varying from a few pounds to 100 pounds per tree. Temperatures in 1944 were relatively high for Michigan, often ranging above 90 degrees F in the shade but never exceeding 96 degrees F. Humidity was comparatively low and rainfall very light. In fact it was one of the driest June-August periods of the past quarter century. The oil-wax emulsion was applied in a 1 per cent concentration (i. e. 1 gallon of the concentrated emulsion to 100 gallons of water) once, twice, and three times to different plots at the same time the regular lead arsenate-insoluble copper combination was used for the control of curculio, fruit fly and leaf spot. Where a single application of the oil-wax emulsion was made there was an average increase in size of the cherries (and consequent increase in yield) of 7 per cent; where two applications were made there was a 15 per cent increase in size; and where three applications were made there was a

30 per cent increase in size. The wax-sprayed fruits were a few days later than the checks in reaching maturity but analyses showed that they contained as much sugar. Perhaps the emulsion simply counteracted the well-known dwarfing effect of the copper fungicide rather than directly affecting size through reduction in transpiration. However, the dwarfing effect of copper sprays on cherries is rather generally attributed to their influence on transpiration rate.

As a Sticker:—In this and in other experiments this new oil-wax emulsion has proven to be a very effective spreader and sticker for the ordinary insecticides and fungicides commonly used in deciduous orchards. For instance, leaves from plots with the emulsion added to the other sprays collected in mid-August carried just a trifle over twice the insecticide and fungicide per unit area as did those receiving the same standard sprays without the emulsion.

Risks and Cautions:—From the statements that have been made, the inference might be gained that these new oil-wax emulsions can be used for many purposes and without any risk of injury to host plant. The work done with them to date indicates clearly that they probably may find extended use for the three objectives mentioned in this paper. Perhaps they will find other uses. They should receive extended trials.

However, certain risks are involved in connection with their use. In our experiments we have observed a marked accentuation of sulfur injury on apple foliage and of copper injury on cherry foliage, when combined with heavy and frequent applications of certain sulfur-containing and copper-containing fungicides. The injuries noted were not due primarily to the emulsion. They were typical sulfur and copper injuries. The effect apparently was due to the "sticking" effect of the emulsion, resulting in increasing the amounts of fungicide adhering to the foliage. Consequently more dilute or less frequent applications of the fungicides are called for when used with the emulsion.

Much experimental work is called for before the place of these materials in horticultural practice is established. However, they possess some qualities not known to belong to other materials that have been applied to plants, and so they open a new field of experimentation and a new approach to certain practical problems in the culture of plants.

Effects of Thinning York Imperial Apples With Elgetol Sprays Applied at Blossom Time[1]

By W. S. FLORY, JR. and R. C. MOORE, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

SINCE Auchter and Roberts (1, 2) in 1933 and 1934 reported their results in preventing fruit set in apples by the application of certain sprays at bloom time, a number of both organic and inorganic spray materials have been used in attempts to effectively control the set of fruit by this method. Elgetol, a sodium salt of dinitrol-cresol, was first suggested by MacDaniels and Hildebrand (4) to be promising as a bloom spray for control of fruit set. At least twenty apple varieties have been mentioned in published reports, by now, as having been experimentally thinned with Elgetol sprays used at blossom time.

There are more trees of the York Imperial apple grown in Virginia than of any other variety. About one-fourth of all apple trees in the state, of bearing age at least, are Yorks (7). This also happens to be one of the most consistent alternate-bearing varieties. Because of these facts, the advantages of any method that would aid in controlling the fruit set on Yorks — either as a thinning aid for a current years crop, or as an aid in modifying the "off-year" tendency, or both — are obvious.

Howlett (3) found that, in Ohio, one application of a 0.6 per cent Elgetol bloom spray prevented fruit set on Yorks. Magness (6) has indicated that satisfactory thinning results might be expected with Yorks from bloom sprays with 0.1 or 0.2 per cent Elgetol. In the present work several different concentrations of Elgetol sprays have been applied at bloom time to York trees of known previous performance. The comparative effects of the different strength sprays on fruit yield, size, color and conformity have been studied.

The apple crop was very light in Southwest Virginia in 1943. Accordingly, the 1944 prospect, since borne out, was for a heavy fruit production. This was, therefore, an ideal year for an experiment of this nature.

METHODS

Forty-eight trees were chosen from a block of York trees which had been set in 1911. These were as similar as could be chosen, in vigor, trunk circumference, and yielding records over the previous 24 years (Table I). They were divided into four groups of 12 trees each; any tree within a block was more similar in general to the other 11 trees of that block, than to trees in any of the other three blocks. By making use of this information the random variability was greatly reduced[2].

[1]Appreciative acknowledgement is made to Dr. Boyd Harshbarger, Station Statistician, for his aid in planning the statistical arrangement of the experiment, and in supervising the data analyses.

[2]This point will be discussed in detail in a separate article.

All trees chosen were developing a heavy bloom in 1944. Most of them had not borne more than 250 pounds, and none more than 500 pounds, of fruit in 1943 (see averages in Table I). More than half produced 75 pounds, or less, of fruit in 1943.

TABLE I—AVERAGES OF PREVIOUS YIELDS AND TRUNK CIRCUMFERENCES OF YORK TREES, AND OF YIELDS FOR THE SAME TREES, AFTER APPLYING ELGETOL SPRAYS AT FULL BLOOM

Elgetol Concentration* (Per Cent)	Average Tree Circumference 1943 (Inches)	Yield (Pounds) 1918 1943 Total	1918 1943 Avg.	1943 Avg	1944 Averages Actual	1944 Averages Corrected**
0.30	44 4	67,950	356	163	700	698
0 25	41.8	56,421	294	76	775	828
0.20	40.6	66,515	346	116	700	706
0 15	45.8	63,604	331	75	1,036	1,052
0 10	46.5	80,193	418	169	1,333	1,248
Check	45.0	62,384	325	156	1,550	1,575
Difference for significance at.						
5 per cent level					359	349
1 per cent level					478	464

*Eight trees in each treatment.
**Corrected by covariance, on basis of 1918-1943 yields.

Five different concentrations of Elgetol, i. e., 0.1, 0.15, 0.2, 0.25, and 0.3 per cent, were used. Each spray was applied to 2 trees in each of the four blocks, or to eight trees in all. All sprays were applied on April 28, 1944, which was the first day of full bloom on which petals had started to fall. This was a warm, quiet day, ideal for spraying. The sprayed trees were drenched thoroughly. An average of 25 gallons of spray was used on each tree. A sixth lot of unsprayed trees, chosen in the same manner as the treated ones, were carried as checks.

Three representative branches, at different positions and heights, were selected on each of the 48 trees. Beginning at the distal end of each branch blossom clusters were counted and a tag placed just proximal to the distal 100 clusters that occurred on spurs 1 inch or more in length. Lateral clusters, or clusters on very short spurs, were removed from these branches. On June 1, just before the "June drop", on June 30, after this drop, and on September 7, just prior to commercial picking, counts of sets and fruits were made on the marked portions of each of these branches. Also on September 7 the fruits on these branches were picked and weighed. Later, complete tree yield records were secured.

Just before the trees were picked a 2-bushel random sample of fruit was secured from each tree. A ladder was set up at four different positions around a tree, and, beginning at the top and working to the base, a half bushel of fruit was secured from each of the four positions. These samples were then passed over a commercial grader and sized. Each sample was also hand graded for color and for conformity. Conformity as considered here covers shape, relative smoothness, presence of stippen, and similar factors affecting grade of fruit.

Effect of Thinning on Yield

Experimental Branches:—Table II, in the column giving the average number of fruits per branch on September 7, lists harvest data based on three branches per tree for the eight trees in each treatment. Thus each average figure is based on fruit counts from 24 branches. The control branches, on unsprayed trees, averaged 84.5 fruits at harvest. Experimental branches on the trees receiving the weakest Elgetol spray, 0.1 per cent strength, averaged 41.3 fruits, a significant reduction below the unsprayed branches. Elgetol spray of the concentrations 0.15, 0.2, 0.25, and 0.3 per cent respectively all resulted in significant thinning differences when compared with selected branches on the unsprayed trees or on those receiving the 0.1 per cent spray. When results from the four stronger concentrations are compared with each other, however, it appears that they produced no important thinning differences on the selected branches.

TABLE II—Effect of Elgetol Sprays Applied at Full Bloom on Yield and Fruit Weight of York Apples*

Elgetol Concentration** (Per Cent)	Average Number of Fruits Per Branch†			Average Weight (Pounds) Per Picked Fruit‡	Average Per Cent of Fruit Dropping	
	June 1	June 30	Sept 7		June 1 to June 30	June 1 to Sept 7
0.30	22.5	19.8	18.1	0.32	12.0	19.6
0.25	34.3	27.5	24.0	0.32	19.8	30.0
0.20	34.1	26.6	24.2	0.32	22.0	29.0
0.15	39.7	26.7	22.3	0.32	32.7	43.8
0.10	67.5	47.1	41.3	0.24	30.2	38.8
Check	114.5	89.3	84.5	0.19	22.0	26.2
Difference for significance at						
5 per cent level	18.1	15.5	14.5	0.07		
1 per cent level	24.2	20.8	19.4	0.09		

*As determined by fruit on three branches per tree, randomly selected.
**Eight trees per treatment.
†Each branch, or part of branch used, bore 100 blossom clusters on spurs one inch or more in ength in 1944
‡Based on apples harvested from experimental branches on September 7.

Average fruit counts per branch both preceding (June 1) and following (June 30) the "June drop" are also presented in Table II. The differences between treatments are rather consistent, for each of the three dates. Column to column comparisons between counts made on June 1 and either June 30 or September 7, give an interesting observation, however. These show that, in our experiment, the proportion of drops after June 1 was considerably less for branches sprayed with 0.3 per cent Elgetol, was about the same where 0.25 and 0.2 per cent sprays were used, and was considerably greater when 0.15 and 0.1 per cent solutions were applied — as compared with drops from the unsprayed controls. The percentages of drops from the selected branches between June 1, and June 30 and September 7, respectively, are shown in the two right hand columns of Table II.

Tree Yields:—In Table I five columns present average yields for the trees used in this experiment. They include: total and average annual individual yields for the 24 year period from 1918 to 1943 in-

clusive; the average 1943 yields, which strongly reflect the low production for that year; the 1944 average tree yields; and the 1944 average tree yields corrected, by convariance, on the basis of records for the 24 preceding years.

For the most part the total 1944 yields, both actual and corrected, were in line with indications from the experimental branches. The trees receiving the three strongest concentrations of Elgetol, i. e., those of 0.2, 0.25, and 0.3 per cent were thinned sufficiently to produce an amount of fruit that was significantly less than that on either the unsprayed check trees or on the trees sprayed with only 0.1 per cent Elgetol. Still the trees receiving the stronger concentrations produced an average of 14 or more bushels of fruit per tree, which is considered a satisfactory commercial crop for them. Some apples on these trees were in clusters but a relatively small amount of hand thinning would have remedied this. In most cases there was no obvious disadvantage to the shape or size of the fruit, resulting from uneven thinning.

It may be pointed out here that while the first leaves to appear were damaged somewhat by the stronger Elgetol sprays, this injury was chiefly marginal burning, was slight, and was scarcely detectable 10 days after applications.

Trees receiving the 0.15 per cent spray were not thinned as much as was expected from fruit counts on the selected branches of these trees. The total yields here were less than those of trees receiving the 0.1 per cent spray — but not significantly so now. On the other hand their yields were considerably more than those of trees receiving the 0.2 per cent spray. In addition, the differences between yields of check trees and of trees sprayed with 0.1 per cent Elgetol were proportionately much less than in the case of the sampled branches.

It has been pointed out (5) that 20 to 25 fruits per 100 blooming spurs would be considered a commercial crop for Wealthy apples. Our 1944 branch and tree yields (Tables I and II) would indicate these figures to be about correct for York apples as well. The trees that received the 0.2, 0.25, and 0.3 per cent Elgetol sprays were adequately thinned, and yet produced good commercial crops of fruit in 1944.

Effect of Thinning on Fruit Size

The 2-bushel random sample of fruit from each tree was run over a Cutler grader and separated into four different sizes. This machine actually graded the apples on the basis of weight and was set so that apples fell into one of the four following weight groups: 4 ounces and under, 4 to 5 ounces, 5 to 6 ounces, or over 6 ounces. These weight groups approximated size classes, in inches, as follows: 2¼ and under, 2¼ to 2½, 2½ to 2¾, or over 2¾. The average numbers of fruit of each size, for each of the several 2-bushel samples in each treatment, are presented in Table III. As is shown by the totals column of this table the number of fruit varied, in some cases considerably, from treatment to treatment. The per cent of fruit in each class, from each treatment, were calculated, and these figures are also shown in Table

III in order that the proportionate numbers of each size may be more easily seen.

It is evident from Table III, that where the four strongest Elgetol concentrations thinned the crop to fewer fruit that the percentage of large fruit (6 ounces and over) is markedly greater than where no spray, or the 0.1 per cent Elgetol spray was used. Conversely, in the case of these two last-mentioned treatments, the number of smaller sized fruit is significantly larger than in cases where the stronger Elgetol solutions were used. This tendency was quite as expected, of course. The point to note is where the chief difference occurs, i. e., between the 0.1 and 0.15 per cent sprays.

TABLE III—EFFECT OF ELGETOL SPRAYS APPLIED AT FULL BLOOM ON FRUIT SIZE OF YORK APPLES*

Elgetol Concentration** (Per Cent)	Average Number of Fruit of Each Size*					Average Per Cent of Fruit of Each Size			
	Under 2¼ in 4 oz	2¼-2½ in 4-5 oz	2½-2¾ in 5-6 oz	Over 2¾ in 6 oz	Total	Under 2¼ in 4 oz	2¼-2½ in 4-5 oz	2½-2¾ oz 5-6 oz	Over 2¾ in 6 oz
0.30	17.0	49.5	46 9	139.5	253	6.2	18.3	18.0	57.5
0.25	28.1	79.1	69.0	98.9	278	9.2	26.4	24.0	40.4
0.20	63.6	90.0	48.8	102 4	305	17.2	27 1	16.6	39.1
0.15	20.1	69.4	77.4	107.5	274	7.1	24.6	25.0	40 8
0.10	148.2	130.0	45.9	48 5	373	36 4	33 8	13.4	16.4
0 00	248.5	104.2	31.9	33 6	423	53 1	25.9	9.3	11 7
Difference for significance at:									
5 per cent level	84 0	40.4	25.2	40.5		14.6	10.5	8 4	18.1
1 per cent level	112 3	54 0	33.7	54.2		19.6	14.0	11.2	24 2

*Based on a two bushel random sample from each tree in the experiment.
**Eight trees in each treatment.

EFFECT OF THINNING ON FRUIT CONFORMITY

In grading two bushel samples from each of the 48 experimental trees for conformity, all apples that were misshapen, rough, or that showed any stippen were eliminated from the Number 1 grade. Fruits that were badly off-shape, unusually rough, or that showed any definite stippen were graded as culls. York apples are more variable in shape and somewhat rougher, of course, than most varieties; this was taken into consideration in the grading work. Fruit of the York Imperial, apparently even more than that of most apple varieties, has a tendency to become "punky" with increasing size. Along with greater size goes increased susceptibility to stippen. Where the sprays of stronger concentrations thinned the crop most extensively, the reflected increase in size of fruit accordingly resulted in a proportionate increase of apples that were "punky". Where an apple obviously fell in this category it was graded as a Utility or lower. Observation of the various lots, after grading, suggested that perhaps the grading was not strict enough with respect to this character, and that some apples of the "punky" type may have remained in the Number one group. Fruits that were misshapen due to apparent lack of pollination, that were injured or roughened mechanically, or that had other defects

obviously not due to effects of the thinning sprays, were not "graded-down" because of these blemishes.

The average number, and also the average per cent, of fruits in each grade, from each treatment, are shown in Table IV. These data, especially when considered with the discussion in the preceding paragraph, suggest that there was a significant decrease in Number one apples following treatments with the four highest spray concentrations, with a corresponding increase in numbers of apples in the lower grades of the same lots.

TABLE IV—EFFECT OF ELGETOL SPRAYS APPLIED AT FULL BLOOM ON FRUIT CONFORMITY OF YORK APPLES*

Elgetol Concentration** (Per Cent)	Average Number of Fruit of Each Conformity Grade			Average Per Cent of Fruit of Each Conformity Grade		
	Number 1	Utility	Culls	Number 1	Utility†	Culls†
0.30	223.2	22.2	7.4	87.0	9.8	3.2
0.25	245.1	22.6	7.8	87.1	9.5	3.4
0.20	275.2	27.0	2 5	88.5	10.5	1.0
0.15	250.9	19.5	4.0	91.3	7.1	1.6
0.10	363 1	6.4	3.1	96.8	2.0	1.2
0 00	400.4	12.5	7.8	94 6	3.2	2.2
Difference for signifiance at:						
5 per cent level	73.0	4.8	5.7	8.8		
1 per cent level	97.6	6.4	7.7	11.7		

*Based on a two bushel random sample from each tree in the experiment.
**Eight trees in each treatment.
†Since several samples covered by these averages contained no fruit of this grade it would be improper to make an assumption for homogeneity of variance in this case. Accordingly differences for significance were not determined.

EFFECT OF THINNING ON FRUIT COLOR

The random sample from each tree was hand-graded for color, on the basis of the "Virginia Standard for Apples". According to the provisions of this standard, York apples, with a good red color characteristic of the variety covering 33 per cent or more of the surface, are graded as Fancy. If the color covers from 15 to 33 per cent of the surface, they are graded Number one, and if less than 15 per cent of the surface, the grade is under Number one. Table V presents the

TABLE V—EFFECT OF ELGETOL SPRAYS APPLIED AT FULL BLOOM ON FRUIT COLOR OF YORK APPLES*

Elgetol Concentration** Per Cent	Average Number of Fruit of Each Color Grade			Average Per Cent of Fruit of Each Color Grade		
	Fancy	Number 1	Under Number 1	Fancy	Number 1	Under Number 1
0.30	75.1	71.4	106.4	28.3	28.4	43.3
0.25	87.6	82.1	105.7	30.6	30.0	39.4
0.20	98.8	102.1	103.8	31.9	33.6	34.5
0.15	83 0	87.9	103.5	30.2	32.0	37.8
0.10	108.2	113.2	151.1	28.4	29.5	42.1
0.00	151.5	120.5	120.5	34.8	29.3	34.7

*Based on a two bushel random sample from each tree in the experiment.
**Eight trees in each treatment.

average number, and also the average percentage, of fruits in each color class, for each spray treatment.

The number of fruits in each grade increased rather consistently as the concentrations of the spray decreased. Thus while the differences between some numbers, of fruits within the same grade, are marked, such differences usually occur between the treatments receiving the lower and the higher spray concentrations, and not between treatments where the spray strengths differed but slightly. Such significance as occurs, then, is an expression of the increasing number of fruits in the samples from the trees receiving the weaker sprays. The data analysis indicated that, in general, no significant difference occurred in the number of apples per color grade, as a result of the different treatments. Where the numbers of fruit in each grade are considered alone there is a suggested difference in the quantity of Number 1 (but not in Fancy nor in under Number 1) fruit following the several treatments. A study of the percentage figures does not substantiate even this difference, however. Rather, it gives further indications of an absence of color difference, in these experiments with York apples, due to thinning with Elgetol sprays.

Summary and Conclusions

1. Elgetol sprays in concentrations of 0.3, 0.25, 0.2, 0.15, and 0.1 per cent were each applied to 8 different York Imperial trees, at time of full bloom. Eight similar trees were selected for use as checks.
2. Spray concentrations of 0.3, 0.25, and 0.2 per cent produced significant and satisfactory thinning in these experiments. Data from selected branches indicated that the 0.15 per cent spray had the same effect, but total tree yields did not substantiate this.
3. Spray concentrations of 0.3, 0.25, 0.2, and 0.15 per cent resulted in significant increases in size and weight of fruit.
4. Application of these same spray concentrations were followed by a reduction, probably a significant one, in quantity of Number one apples — because of more roughness, stippen, etc., in the larger apples that resulted from thinning.
5. Thinning York apples with Elgetol sprays did not cause any color differences, in these experiments, in the harvested fruit.
6. The 0.2 per cent Elgetol concentration was as satisfactory in its thinning results as the stronger solutions used. It was also as advantageous, and no more disadvantageous, in other respects. Because of this, of material economy, and of lessened chance of foliage burning, the 0.2 per cent concentration may be considered the most efficient of the Elgetol sprays used in this experiment at Blacksburg in 1944.

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The Mode of Action of the Pollenicide, Elgetol

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THAT Elgetol (sodium-dinitro-orthocresol) is a pollenicide was first demonstrated in 1938 incidental to a preliminary laboratory experiment testing this material on a number of phytopathogenic fungi and bacteria for its fungicidal and bactericidal properties (2, 3). Pollen germination experiments were conducted employing apple and pear pollen and 5 per cent sucrose agar containing several dilutions of Elgetol (none, 1–100, 1–500, 1–1000). With pollen germination completely prevented even in the 1–1000 concentration, it was concluded that Elgetol possessed the property of being a pollenicide.

This work was resumed in February, 1939, employing small pomaceous (apple, pear, quince) and prunaceous (peach, plum, cherry) trees bearing blossoms in the greenhouse. The effect of the pollenicide on pollen germination was tested on 5 per cent sucrose agar and also *in situ* on the stigmatic surfaces of the pistils of all the flowers of these fruits and found to be pollenicidal to all pollens at the two dilutions tested (1–250, 1–1000).

Studies were also conducted employing both pear and apple pollen to determine the dilution upper limits of Elgetol as a pollenicide. The highest dilution still pollenicidal was approximately 1–10,000.

Because of its horticultural potentialities, experiments were conducted in May, 1939, in an attempt to find the concentrations of Elgetol safe and effective for use on orchard trees. The results of these studies (6) established the fact that a 0.3 per cent solution was the highest concentration safe to use on the open blossoms of apple. Subsequently, much work has been done on the adaptation of this pollenicide to orchard use (4, 5).

In an attempt to define the mode of action of Elgetol in the blossoms of orchard trees, difficulties were encountered in the form of frost injury to the blossoms (3).

Because frosts destroyed much of the bloom two years in succession in these orchard experiments, it was decided to conduct the detailed studies on dwarf apple and pear trees forced in the greenhouse, supplemented by bouquets. Also, field work was conducted on pear and apple on an orchard scale with emphasis on complete blossom removal from blight susceptible varieties. This involved the use of trees two or three years from planting till bearing age was reached 3 to 5 years later.

This investigation had several objectives, one of which was to determine whether treated pollen is permanently inactivated. This point was easily determined by atomizing a quantity of pollen with Elgetol solution, and after drying, testing for germination on sucrose agar. Regardless of the concentration of Elgetol used (0.1, 0.2, 0.3 per cent) or whether the pollen was washed with water and dried before testing, treated pollen was incapable of germination.

Another objective was to determine whether there is a material which would form an effective barrier against pollen tube penetration

and fertilization of pear flowers. Although injury sometimes followed, brushing melted paraffin on the pistils preceding the application of pollen prevented fertilization.

The main objective was to find the more exact interval following pollination that the pollenicide is capable of preventing fruit set. By virtue of its ability to penetrate through the stigmas into the pistil, the effective depth of penetration down the style is apparently a function of concentration and rate of dilution with distance. Also vigor of the pollen and temperature are factors influencing the time interval. It is obvious, too, that a 0.3 per cent concentration would have a more effective range of penetration than the weaker dilutions.

Laboratory Experiments

The laboratory studies conducted on pollen inactivation on the stigmatic surfaces of pistils by McDaniels and Hildebrand (1940) were repeated and confirmed and extended to include pollens of plants other than apple, namely, pear, quince, peach, plum, and cherry. The procedure was to dust suitable pollen on the blossoms and at several intervals thereafter — immediately, and at intervals of 1, 3, 5, 7, 15, and 24 hours — to spray with several concentrations of Elgetol (1–1000, 2–1000, 3–1000) and then to promptly examine the stigmatic surfaces by excising the blossoms and immersing the pistil tips in melted celloidin on glass slides, after the technique described by MacDaniels and Hildebrand (6). At room temperature (about 22 degrees C) most of the pollens in the unsprayed checks were already beginning to germinate within four hours from pollination, with the result that the remains of the pollen grains could not be readily held by the partly solidified celloidin, when the excised pistils were withdrawn. Consequently, this study was largely limited to the intervals between one and seven hours after pollination.

As the result of this study, it can be concluded that all the pollens tested were completely inactivated by Elgetol in all concentrations tested. When the interval of spray application ranged from 8 to 15 hours after pollination, the pollen tubes which had penetrated down the pistils some distance were also inactivated.

To locate the actual depth of penetration and the condition resulting from the use of Elgetol the upper two-thirds of the pistils were carefully macerated on glass slides in an attempt to follow the germ tube starting at the stigmatic surface and progressing downward.

Pollen was also placed on sucrose agar to germinate and received the Elgetol treatment at the same intervals as above. This resulted in all cases in the permanent arresting of germination and pollen tube elongation, regardless of the stage when sprayed. It would appear then that Elgetol inactivates the pollen before and after germination, whether outside or inside the pistil, but this still leaves unsettled the interval after pollination that Elgetol is able to prevent fertilization.

Greenhouse Experiments

In the greenhouse studies on Elgetol blossom sprays, the best test material proved to be dwarf pears. The varieties mainly used were

Bartlett, Dutchess, and Kieffer. Ordinarily, Bartlett was used for providing blossoms and the others for pollenizers. From ten to thirty trees were used in an experiment. The procedure was to dust pollen on the open blossoms and then to apply the pollenicidal spray at selected intervals thereafter. Numerous experiments were run over a period of five years employing three concentrations of the pollenicide (0.1, 0.2, and 0.3 per cent).

In one representative experiment, conducted at a temperature which fluctuated between 65 degrees and 70 degrees F, the 0.3 per cent dilution penetrated and effectively prevented fertilization to the depths that the pollen tubes could reach in approximately 24 to 30 hours after pollination. Some injury to the styles was evident. The corresponding intervals for the 0.2 and 0.1 per cent concentrations were approximately 24 and 20 hours after pollination. In many similar experiments, although the results were not identical, the relation between concentration of Elgetol and interval after pollination it was effective as a pollenicide remained in the same order.

Following the movement of the pollen tube down the style of the pistil was difficult by means of tissue examination because of its extreme structural delicacy. The usual technique of maceration on glass slides in 70 per cent ethyl alcohol was far from satisfactory. Moreover, employing stains such as Cotton Blue for differentiation of the extremely delicate pollen tubes from the surrounding tissues gave rather uncertain results. Because of the uncertainties of direct examination, parallel experiments were conducted for estimating depth of pollen tube penetration by an indirect method. This technique consisted simply of cutting off the pistils with a small bladed scissors at various distances below the stigmatic surface.

That the depth of pollen tube penetration inactivated by 0.3 per cent Elgetol approximates midway down the style of the pistil is illustrated in one experiment in which sprayed and unsprayed blossoms had their pistils clipped off approximately midway down the styles. (Table I) Repetitions of this experiment gave similar results. It should

TABLE I—COMPARATIVE EFFECTS OF SPRAYING WITH 0.3 PER CENT ELGETOL AND REMOVAL OF UPPER HALF OF PISTILS BY CLIPPING ON FRUIT SETTING OF BARTLETT PEAR

Interval (In Hours)	Number of Fruits Set in Average* Clusters Thinned to 5 Blossoms at 9- and 17-day Intervals After Pollination							
	Unsprayed				Sprayed			
	Unclipped (Days)		Clipped (Days)		Unclipped (Days)		Clipped (Days)	
	9	17	9	17	9	17	9	17
8	4½	2	0	0	0	0	0	0
24	4½	2	1	½	1	½	0	0
32	5	2	2½	1½	1½	1½	2	2
48	5	3	5	2	5	2	5	1½
56	4½	2½	4½	4	4	2½	4	2
72	5	3	4½	2	5	3	5	2½

*4 or more clusters per treatment. The 9- and 17-day intervals were arbitrarily chosen in this experiment. The intervals used in other experiments were 10 and 21 days.

be noted that when the blossom clusters were thinned to five at the start of the experiment, that clipping of sprayed blossoms was slightly more effective than clipping unsprayed blossoms at 24 hours after pollination.

In subsequent experiments, trees were used with their blossom clusters reduced to 10 or less, depending on the size of the tree. Also, each blossom cluster was thinned to three blossoms at as nearly the same stage of blossom development as possible, to compensate for the apparent advantage possessed by the blossom most advanced in development at time of pollination.

In the first experiment, of the 60 unsprayed checks, 56 set and 20 continued development toward maturity, being nearly half grown when the final data were taken. Of those sprayed 15 to 20 hours after pollination, none set. Those sprayed 24 hours after pollination gave a very low set of about 5 per cent. At the 2-day interval, 52 set and 17 developed toward maturity. At 3 days, 53 set and 18 developed toward maturity. Many of these fruits were carried to maturity by proper handling of the trees, to maintain good growth. Ordinarily, one cluster was able to mature one fruit. When harvested the fruits were found to contain fully developed seed with the number averaging slightly over one to the locule. This experiment was repeated three years in succession with similar results.

A further modification of technique was employed in which the middle blossom of the three retained in the cluster served as a pollinated check and received the clipping treatment. In this experiment three dilutions of Elgetol (0.1, 0.2, 0.3 per cent) were compared at 0, 15, 20, 24, 28, 32, 40, and 48 hours after pollination, for prevention of fruit set. The air temperatures ranged from about 60 degrees at night to 75 degrees F in daytime. The results of this experiment can be summarized thus: The pollenicide by virtue of its penetration into the pistil of pear blossoms moved a distance roughly comparable to that of the pollen tubes over a period of approximately 24 hours. For intervals greater than 24 hours there was a rapid dropping off in fruit set prevention until at 32 hours even the most concentrated (0.3 per cent) solution of Elgetol had no effect. While the 0.3 per cent concentration was effective practically 100 per cent in preventing fertilization and fruit set, if applied within 24 hours after pollination, the 0.2 and 0.1 per cent concentrations gave similar results at shorter intervals of 20 to 24 and 15 to 20 hours after pollination. Again in the clipped checks fruit set had begun to appear at the 32-hour interval.

Miscellaneous Experiments

Several experiments were conducted on the potentialities of Elgetol as a bactericide. The results of experiments conducted over a period of years can now be summarized. In all cases the blossoms were pollinated at the beginning of the experiments. When blossoms were atomized with bacteria several hours ahead of spraying with Elgetol at the usual dilutions, 100 per cent infection resulted. When inoculated with bacteria and sprayed with Elgetol simultaneously, practically

100 per cent blossom blight resulted. Atomization with bacteria 1 day after spraying with Elgetol gave an average of about one blossom blighted per average cluster and at 2 days gave only a trace of blossom blight. These results are in accord with previous observations that Elgetol is not a bactericide at weak dilutions.

As a pollenicide Elgetol has several uses in fruit culture. In bearing orchards, fruit thinning is important (4, 5). Also important is blossom removal by spray instead of by hand in a blight-susceptible, young pear orchard before reaching bearing age.

Several growers working in cooperation with the writer sprayed their young pear orchards (1 quart Elgetol in 100 gallons of water) as nearly as possible to when the bulk of the blossoms were first opened, with promising results. The occasional blossoms not removed by this treatment can be readily pinched off by hand. In a check orchard of between 8 and 9 acres, all the blossoms were removed by hand until the trees reached bearing age. This hand job is so laborious and time consuming that few growers can do it. Any grower with a blossom blight problem in his young trees should consider the blossom spray.

Discussion and Conclusions

Judging by terminology, Hoffman (4) and others consider the mode of action of Elgetol in blossom thinning to be that of a poison or toxin by labeling it a caustic material which connotes that when applied to the open blossoms it kills the tissue or that the pollinating insects are being subjected to poisoning. Since the prime function of Elgetol in blossom removal is that of a pollenicide this seems to be the logical term to use, especially when considered in relation to its other functional properties, namely, that of being a fungicide and an insecticide. Preliminary studies indicate that forced feeding of bees in confinement shortens the life span. However, bees appear not as readily attracted to sprayed as to unsprayed blossoms. Although lacking published evidence that Elgetol is a serious lethal hazard to pollinating insects, this phase of the problem deserves careful study. It is therefore suggested that the term "pollenicide" and not "caustic spray" should be used for a material that functions primarily to prevent fruit set, although injury sometimes results to the stylar tissue.

No doubt materials other than Elgetol will be found which are pollenicidal. The first material showing such promise to the writer was "Pink Dust" which contained phenol and is highly injurious to blossom tissues. More recently tests have been made using dilute concentrations of the herbicides sodium chlorate, sulfamic acid, ammonium sulfamate, and several growth substances. This work was still in preliminary stages when discontinued this year, but several of the materials, when well diluted, were definitely pollenicidal.

The experiment using paraffin wax for coating the stigmas of blossoms demonstrated that the wax would function only as a mechanical barrier to pollen tube penetration and not interfere with the pollen already present, unless impregnated with a pollenicidal material like Elgetol.

Several growers working in cooperation with the writer have tested Elgetol for thinning peaches. Variable results were obtained. One grower estimates a saving of between $500 and $700 in cost of thinning by a bloom spray of a few hours made on part of his large orchard in 1944.

Hoffman has pointed out (4, 5) that variety of fruit and vigor of tree are important factors when deciding on strength of material to use and length of interval to be allowed to pass after opening of the blossoms before applying the pollenicide. A recommendation can be made under New York conditions which allows the first opening blossoms of apple 2 days' time to elapse for fertilization before application of the pollenicidal spray. This coincides with the early full bloom stage of blossom development, or when the pollenicide should be applied to be most effective.

The mode of penetration of Elgetol into the pistils is through the exposed intercellular spaces of the stigmas, that is, natural openings. However, no thoroughly reliable technique has been developed for directly determining the depth of penetration that pollen tubes are inactivated. The indirect method of clipping off the pistils at different levels below the stigmatic surface established the fact that a 0.3 per cent solution of Elgetol is apparently able to inactivate pollen tubes to midway down the style of the pistil or the depth of penetration of pear pollen approximately one day after the pollen has been applied to the stigmatic surface. The studies on the more exact effect of temperature on the time interval were not worked out.

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Reducing the Set of Pecan Nuts by Spraying in Flower With Phytotoxicants

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The studies of Crane *et al.* (1) and of Sitton (4) have shown that under the conditions of their tests the degree of kernel development of the pecan nut and the regularity of nut crop production were related to the average number of leaves per nut on the tree. These workers found that three leaves or less per nut resulted in a crop of nuts with poorly developed kernels. With four to six leaves per nut the kernel development was satisfactory but frequently no crop was produced by the trees the following year. They found that when a tree had more than six leaves per nut a crop with well-developed kernels was produced, and this was followed by another crop the next year.

A number of prolific varieties of pecan (*Carya illinoensis,* K. Koch.) will frequently set more nuts than it is possible for the trees to properly fill. In these cases it is advantageous to reduce the number of nuts on the trees. The successful use of a toxicant spray during bloom to reduce the set of apple fruit, (3, 6) has suggested tests with pecans for the same purpose. The studies reported here were conducted to investigate the possibility of reducing the set of nuts by spraying in flower with a preparation having phytotoxic properties.

Experimental

Season of 1943

Materials:—This study was begun in 1943. Thirteen-year-old pecan trees of the Success variety in a very high condition of vigor and bearing a fairly large number of pistillate flowers were used. All the trees were comparable as regards size, vigor, and flowering. They were growing in a Miller clay soil and had been given clean summer cultivation followed by a vetch winter cover crop plowed under in April. Observations made in 1943 of the time of pollen shedding and the adherence of pollen to the stigmas showed no adherence on Success until April 28. Success shed pollen from April 27 to May 3; adjoining Schley trees, from May 3 to 9; and nearby Stuart trees, from May 3 to 11. Thus, pollen was available for two weeks for the pistillate flowers in this study, which should have insured adequate pollination.

Methods:—Ninety-three limbs of similar size on nineteen Success trees were used. These limbs had an average of twenty-five pistillate flower clusters each on May 27. The pistillate and staminate flowers and the foliage of these limbs were sprayed with the several materials at various times from April 28 to May 3. Some limbs were sprayed only once, and some were given a second application two or three days after the first. The spraying was done with a three-gallon compressed air sprayer.

Single applications of Elgetol (a sodium salt of dinitro-cresol with the addition of a penetrating agent) at strengths of 0.01, 0.02, 0.05, 0.10, 0.20, and 0.50 per cent; and two applications at 0.10 and 0.20

per cent were used. Single applications of 4–1–100 bordeaux, one and two applications of bordeaux 6–2–100, and one and two of Fermate 2–100 were also made.

Counts were made on May 27 of pistillate clusters and pistillate flowers on each sprayed limb. These counts were made before there had been any apparent drop of flowers from faulty pollination or damage by the nut case-bearer. The clusters and nuts were again counted on June 8, and no drop from faulty pollination was apparent afterwards. At that time most of the nuts that had been injured by the nut casebearer were still adhering to the peduncles, and the counts of clusters and nuts so injured were recorded. The number of infested nuts was subtracted from the May 27 count in making the calculation of the percentage of flowers that set.

Results:—Data on the percentage of the pistillate flowers setting nuts after being sprayed with the various fungicides are presented in Table I. These data have been analyzed by the analysis of variance method for unequal numbers as given by Snedecor (5). Differences between the percentages of set resulting after the flowers were sprayed with .2 or with .5 Elgetol and those sprayed with .01 or .05 per cent Elgetol are highly significant (1 per cent level). No other difference is significant. The least reduction occurred with Elgetol at strengths of 0.10 per cent or weaker, and the greatest reduction with Elgetol at strengths of 0.20 and 0.50 per cent. The reduction in set caused by bordeaux and by Fermate was intermediate.

TABLE I—EFFECT OF SPRAYING SUCCESS PECAN PISTILLATE FLOWERS WITH VARIOUS PHYTOTOXICANTS ON THE PERCENTAGE NUTS SET, 1943

Material Used	Strength of Material	Percentage of Flowers Setting Nuts*	Number of Limbs Used
	One Application		
Elgetol	.01 per cent	83	5
Elgetol	.02 per cent	69	6
Elgetol	.05 per cent	89	4
Elgetol	.10 per cent	69	10
Elgetol	.20 per cent	57**	15
Elgetol	.50 per cent	40**	12
Fermate	2–100	65	15
Bordeaux	4-1-100	56	4
Bordeaux	6-2-100	67	13
	Two Applications		
Elgetol	.10 per cent	67	2
Elgetol	.20 per cent	55	3
Fermate	2-100	47	2
Bordeaux	6-2-100	62	2

*No counts were made on unsprayed limbs

**Highly significant (1 per cent level) difference in comparison with Elgetol .01 per cent and Elgetol .05 per cent.

SEASON OF 1944

Materials:—Work in 1944 to control the set of pistillate flowers by spraying with fungicides was all done by spraying whole 14-year-old trees of Mahan, Moore, Nelson, Desirable, Stuart, and Success varieties. Comparable trees of the same variety were left unsprayed as checks.

One block of trees of each variety was located on Miller loam soil in a variety test planting, and there was a second block of Moore on Miller clay soil in a planting of trees used as part of a pruning experiment located about half a mile from the variety orchard. The variety test orchard contained fifty varieties and seedlings which shed pollen at different times from April 18 to May 9. This abundance of pollen should have insured adequate pollination for the varieties used in this study. Records for the "pruning" block of Moore showed that pollen dissemination from neighboring trees during the time of pollen adherence to the stigmas may not have been sufficient for a maximum set, and counts made later on the drop of the flowers confirmed this.

Methods:—Two applications of bordeaux 4–1–100 were used on all varieties. Spraying was done from April 20 to 27 with a power sprayer at five hundred pounds pressure, using a Bean spraymaster gun equipped with a disc having a 10/64-inch orifice. As far as possible the spray was applied as a "fog".

The pistillate flowers and clusters on large lower limbs of the sprayed and the unsprayed trees were counted the first week of June, before there was any apparent drop because of faulty pollination. The count after the drop from faulty pollination had occurred was made the second week of July. Approximately 5 per cent of the nuts were damaged by nut case-bearer, but no consideration is given this loss since it was distributed quite uniformly. The counts were made on large limbs, thereby obtaining samples in which the amount of the infestation was fairly uniform among treatments.

Results:—Data showing differences in the set of nuts on the sprayed and the unsprayed trees are presented in Table II. The significance of the difference between the sprayed and the unsprayed trees has been determined by the method of Fisher (2) for determining the significance of the difference between means of small samples. These data show that two applications of bordeaux to the Moore trees in the pruning block caused 25 per cent of the pistillate flowers to fail to set nuts. Two applications of bordeaux to the Moore trees in the variety orchard resulted in 27 per cent of the flowers failing to

TABLE II—Effect of Spraying the Pistillate Flowers of Several Varieties of Pecans with Bordeaux 4–1–100 on the Percentage Setting Nuts, 1944

Variety	Percentage of Pistillate Flowers Setting Nuts			Earliest Date of Pollen Adhering to Stigmas	Dates Spray was Applied
	Mean of Sprayed Trees	Mean of Unsprayed Trees	Mean Diff.		
Moore Pruning Test Orchard	28	53	25**	4-26	4-24 & 4-27
Moore Variety Test Orchard	65	92	27**	4-26	4-22 & 4-24
Mahan	65	77	12	4-19	4-20 & 4-22
Nelson	38	50	12	4-24	4-22 & 4-24
Success	56	59	3	4-21	4-22 & 4-24
Desirable	54	59	5	4-21	4-22 & 4-24
Stuart	75	79	4	4-21	4-22 & 4-24

**Highly significant (1 per cent level) mean difference.

set. These differences between the set on the sprayed and the unsprayed trees are both highly significant. The reduction in the set was much less for the other varieties, and the differences between the sprayed and the unsprayed trees are not significant. It is possible that these varieties were sprayed too late for the spray to inhibit the setting.

Discussion

The results obtained in these studies show that it is possible to inhibit partially the setting of nuts on pecans by spraying with 4–1–100 bordeaux at or shortly before the time pollen first adheres to the stigmas.

It was apparent in this study that the availability of pollen at the right time for pollination is quite important, and can effect the set of nuts more than the spray treatment. This is brought out by the fact that with adequate pollen available the set on the unsprayed Moore trees in the variety orchard was 92 per cent, while unsprayed trees of this variety in the pruning block that had inadequate pollination set only 53 per cent of their pistillate flowers. Even after the setting of 27 per cent of the flowers on the Moore trees in the variety orchard had been prevented by the spray applications, there were more nuts on the trees than there were on the unsprayed Moore trees in the pruning block.

Conclusion

The set of nuts by the pistillate flowers of the pecan can be reduced by spraying with certain phytotoxic materials at or shortly before the time pollen first adheres to the stigmatic surfaces.

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Further Studies on the Effect of Certain Chemicals on the Fruit Set of the Apple

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PRELIMINARY tests carried out in 1942 (1), to determine the effectiveness of various materials in reducing the fruit set of apples were successful in that certain materials were found to be promising. This report includes additional work on phases of the problem that were not completed. It covers a follow-up of limb behavior of previous years, and in addition it gives the results obtained with several new materials.

1943 Records on 1942 Treated Limbs

Records taken of the off year (1943) on limbs treated in 1942 gave results which varied considerably, particularly between varieties. Generally speaking, the varieties definitely alternate in fruiting habit, such as Delicious and Gano, had very few flowering points in 1943. The Delicious and Gano limbs that were treated in 1942 had few if any more flowers than the untreated or check limbs, which had practically no flowers, even though these treatments did significantly reduce the set in 1942. It is not known why those limbs on which set was virtually prevented failed to produce a greater number of flowering points for 1943.

In the case of the Arkansas Black, which produces a fair crop each year, but which does have some fluctuation or alternate tendency, the opposite was the case, for generally speaking, all treatments that significantly reduced set in 1942 produced more flowering points in 1943 than did the check limbs. In most cases that difference was not great enough to be significant at the 5 per cent level. The one exception to this was in the case of a comparison of two strengths of naphthalene acetic acid and naphthalene acetamide. These materials were each used at .01 per cent and .03 per cent concentrations. In this test the naphthalene acetic acid applied in 1942 not only reduced set in 1942, but also significantly reduced the number of flowering points formed for 1943. The percentages of flowering points in 1943, as compared with 1942 (calculated by dividing the number of flowering points in 1943 by the number of flowering points in 1942), were as follows: naphthalene acetic acid .01 per cent, 39.6; naphthalene acetic acid .03 per cent, 12.5; naphthalene acetamide .01 per cent, 73.1; naphthalene acetamide .03 per cent, 84.9; and the untreated check limbs, 67.6. These figures are an average of 10 replications. In view of this apparent carry-over effect on Arkansas Black, it may be possible to use naphthalene acetic acid as an off-year spray on other varieties which are definitely alternate in bearing habit as a means of reducing the number of on-year flowering points and thereby reducing the crop. Further tests along these lines are in progress.

Tests Conducted in 1943

Since 1943 was the off year, three additional growth-regulating substances were tested, in an effort to find a means of increasing the off-year set. The materials tested were indole butyric acid, indole acetic acid, and indole propionic acid. These materials were tested at three strengths. The data shown in Table I are the results of the tests on Stayman Winesap. As may be noted in Table I, none of the materials at any of the strengths used had any significant effect on the percentage of flowering clusters that set fruit or matured fruit in 1943.

TABLE I—The Results of Spraying Stayman Winesap Flowering Points with Certain Chemicals 1943

Treatment*	Number of Limbs	Average Per Cent of Flowering Points Setting	Difference Necessary for Significance at 5 Per Cent Level	Injury to Leaves	Injury to Spurs	Average Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
			One Application in Full Bloom				
1	6	48 1	Not significant	None	None	33 7	Not significant
2	6	44 9		None	None	32 3	
3	6	46 2		None	None	27 2	
Ck	6	38 0				22.6	
			One Application in Full Bloom				
4	10	32.8	Not significant	None	None	15.6	Not significant
5	10	32.2		None	None	18.1	
6	10	38 7		None	None	22.7	
Ck	10	45.9				24 6	
			One Application in Full Bloom				
7	7	45.1	Not significant	None	None	22.0	Not significant
8	7	47 0		None	None	31.3	
9	7	39.5		None	None	21.2	
Ck	7	33.7				20.8	
			One Application in Full Bloom				
24	6	39.6	Not significant	None	None	28.6	Not significant
25	6	41 5		None	None	28 7	
26	6	47 1		None	None	26.9	
Ck	6	51 1				30 8	

*Key to spray materials:
1 = .005 per cent indole butyric acid.
2 = .01 per cent indole butyric acid.
3 = .03 per cent indole butyric acid.
4 = .01 per cent indole acetic acid.
5 = .02 per cent indole acetic acid.
6 = .04 per cent indole acetic acid.
7 = .005 per cent indole propionic acid.
8 = .01 per cent indole propionic acid.
9 = .03 per cent indole propionic acid.
24 = .0005 per cent borax.
25 = .005 per cent borax.
26 = .05 per cent borax.

It is known that rather low concentrations of boron are toxic to certain plants and plant parts; hence it was thought such a material might be of value as a spray to reduce set. The foliage and wood of apple trees are not easily injured by fairly heavy and rather frequent applications of boron. Other work at this Station where borax was added to codling-moth sprays showed that the vegetative behavior of the trees was not visibly affected. In view of this, sprays of boron in

the form of borax, at concentrations of .0005, .005, and .05 per cent, were used. None of these sprays significantly reduced the set or crop of Stayman Winesap.

The experiments on Arkansas Black included indole butyric acid and indole acetic acid, in addition to a continuation of tests with naphthalene acetic acid, naphthalene acetamide, and di-nitro-ortho-cyclo-hexyl-phenol. The results of these tests are shown in Table II. It may be noted that at the concentrations used, indole butyric acid and indole acetic acid failed to affect set of Arkansas Black significantly.

Tests to determine concentrations of naphthalene acetic acid and naphthalene acetamide that would reduce set were made, even though it was the off crop year. The former material, used a concentrations of .002 and .004 per cent, significantly reduced set; however, the matured crop was very light as a result of a heavy drop, so that there was no significant change in the percentage of flowering points maturing fruit. Naphthalene acetamide at strengths of .004 and .008 per cent did not significantly affect the set or crop. Di-nitro-ortho-cyclo-hexyl-phenol used at .20 and .25 per cent concentration did not significantly

TABLE II—THE RESULTS OF SPRAYING ARKANSAS BLACK FLOWERING POINTS WITH CERTAIN CHEMICALS 1943

Treatment*	Number of Limbs	Average Per Cent of Flowering Points Setting	Difference Necessary for Significance at 5 Per Cent Level	Injury to		Average Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
				Leaves	Spurs		
			One Application in Full Bloom				
1	7	8.3	Not significant	None	None	3.7	Not significant
2	7	6.5		None	None	2.2	
3	7	8.2		None	None	4.9	
Ck	7	8.4				2.0	
			One Application in Full Bloom				
4	6	7.0	Not significant	None	None	2.3	Not significant
5	6	4.3		None	None	2.7	
6	6	5.0		None	None	2.8	
Ck	6	6.1				1.9	
			One Application in Full Bloom				
10	6	13.8	3.5	None	None	1.1	Not significant
11	6	18.1	——	None	None	0.4	
12	6	7.8	——	None	None	0.6	
13	6	5.4	——	Slight	None	0.8	
Ck	6	14.1	——			1.8	
			One Application in Pre-pink to Pink				
19	6	7.1	Not significant	Slight	Very slight	0.4	Not significant
20	6	4.3		Moderate	Slight	0.7	
Ck	6	9.0				2.1	

*Key to spray materials:
1 = .005 per cent indole butyric acid.
2 = .01 per cent indole butyric acid.
3 = .03 per cent indole butyric acid.
4 = .01 per cent indole acetic acid.
5 = .02 per cent indole acetic acid.
6 = .04 per cent indole acetic acid.
10 = .004 per cent naphthalene acetamide.
11 = .008 per cent naphthalene acetamide.
12 = .002 per cent naphthalene acetic acid.
13 = .004 per cent naphthalene acetic acid.
19 = .20 per cent di-nitro-ortho-cyclo-hexyl-phenol.
20 = .25 per cent di-nitro-ortho-cyclo-hexyl-phenol.

affect the crop or set of fruit. None of the materials tested in 1943 caused a serious amount of damage to the leaves or spurs, however, the di-nitro-ortho-cyclo-hexyl-phenol caused the most injury of all of the 1943 treatments. The injury was to the young leaves, and the treated limbs had made satisfactory recovery within about a month after the date of application.

Records were made in 1944 on the number of flowering points formed during 1943. These data show that none of the treatments applied in 1943 significantly affected fruit bud initiation or development that year.

1944 Tests

Scaffold limbs of Arkansas Black were used in the comparisons of the following materials: Reico, .08 per cent; Hormex at 2 times the recommended strength for preharvest spray (.002 per cent naphthalene acetic acid plus an activating agent); di-nitro-ortho-cyclo-hexyl-phenol, .25 per cent; naphthalene acetic acid, .004 per cent; and naphthalene acetamide, .008 per cent. Table III gives the data obtained from this experiment. It may be noted that all materials except Hormex significantly reduced fruit set and the percentage of flowering points that matured fruit. The naphthalene acetamide was effective and had the further advantage of causing no visible leaf or spur injury. The injury caused by the other effective sprays was not severe and could be ranked in the following order: naphthalene acetic acid, di-nitro-ortho-cyclo-hexyl-phenol, and Reico, with the material last mentioned causing the most injury. Recovery was slowest in the case of naphthalene acetic acid.

Further scaffold tests on Arkansas Black, using naphthalene acetic acid, were made in which a wetting agent, Vetsol K, was added to the spray at the rate of 4 oz/100 gal. Both strengths (G & H treatments in Table III) gave a significant reduction in set. The concentrations had the same effect on the percentage of flowering points that matured fruit. In limb tests, a comparison of strengths of naphthalene acetic acid with and without a wetting agent, the following combinations were used: (a) naphthalene acetic acid .002 per cent, (b) the same material and concentration plus Vatsol K 3 oz/100 gal., and (c) naphthalene acetic acid .001 per cent plus Vatsol K, 3 oz. per 100 gallons of spray (treatments J, K, and L in Table III). Limbs sprayed with .002 per cent naphthalene acetic acid were not significantly affected, whereas limbs treated with a similar spray containing the Vatsol K had a significantly lower set. When the wetting agent was used, a .001 per cent spray reduced set, although a .002 per cent spray without the wetting agent did not. The only treatment that significantly reduced the percentage of flowering points that matured fruit was the .002 per cent concentration with Vatsol K. The naphthalene acetic acid sprays used in the test caused no visible injury on the tree.

Tests of a boron spray applied to Arkansas Black limbs in which borax was used were made. Strengths tried were .05 per cent, .5 per cent and 1.0 per cent by weight and are shown as N, O, & P in Table

TABLE III—The Results of Spraying Arkansas Black Flowering Points with Certain Chemicals 1944

Treatment*	Number of Limbs	Average Per Cent of Flowering Points Setting	Difference Necessary for Significance at 5 Per Cent Level	Injury to Leaves	Injury to Spurs	Average Per Cent of Flowering Points Maturing Fruit	Difference Necessary for Significance at 5 Per Cent Level
			One Application in Pink				
A	5	3.4	7.9	Considerable	Moderate	3.1	7.7
			One Application in Full Bloom				
B	5	9.1	——	Very little	None	17.4	——
			One Application in Pink				
C	5	16.9	——	Some	Slight	13.4	——
			One Application in Full Bloom				
D	5	7.5	——	Slight	None	7.5	——
E	5	14.8	——	None	None	12.3	——
Ck	5	26.4	——			26.4	——
			One Application in Full Bloom				
G	5	5 5	6.7	Less than D	None	3.5	6.2
H	5	2.4	——	Considerable	None	1.1	——
Ck	5	15.5	——			13.8	——
			One Application in Full Bloom				
J	6	6.5	7.0	None	None	5.9	7.8
K	6	24.0	——	None	None	22.7	——
L	6	19.7	——	None	None	16.5	——
Ck	6	29.7	——			22.6	——
			One Application in Full Bloom				
N	6	28.1	10.2	None	None	21.8	Not significant
O	6	24.9	——	None	None	18.7	
P	6	20.7	——	None	None	16.3	
Ck	6	35.5	——			24.6	

*Key to spray materials:
A = .8 per cent Reico.
B = .002 per cent naphthalene acetic acid (Hormex).
C = 25 per cent di-nitro-ortho-cyclo-hexyl-phenol.
D = .004 per cent naphthalene acetic acid.
E = .008 per cent naphthalene acetamide.
G = .003 per cent naphthalene acetic acid plus Vatsol K (4 oz/100 gal).
H = .01 per cent naphthalene acetic acid plus Vatsol K (4 oz/100 gal).
J = 002 per cent naphthalene acetic acid plus Vatsol K (3 oz/100 gal).
K = .002 per cent naphthalene acetic acid.
L = .001 per cent naphthalene acetic acid plus Vatsol K (3 oz/100 gal).
N = .05 per cent borax.
O = .5 per cent borax.
P = 1.0 per cent borax.

III. It may be noted that the two stronger concentrations caused a significant reduction in set. There was, however, no significant difference between treatments in the percentage of flowering points that matured fruit. It should also be pointed out that these sprays had no visible effect on the foliage or spurs of the tree.

Discussion

Results secured from tests conducted during the last three years indicate that certain chemicals show promise as a means of reducing the on-year crop. Some of the materials tested (Reico, di-nitro-ortho cresol, di-nitro-ortho-cyclo-hexyl-phenol, Elgetol) have reduced

set; however, when used at strengths which affected the set, they also caused considerable injury to the tree, in many cases more than would seem desirable.

Naphthalene acetic acid shows considerable promise as a material to reduce set. Strong concentrations (.01 and .03 per cent) practically entirely eliminated set, caused considerable leaf injury, and also caused a significant reduction in flowering points formed for the following year on the Arkansas Black variety. This suggests the possibility of using this material as an off-year spray to reduce flower bud formation for the on-year crop. Tests in which naphthalene acetic acid was used at a lower concentration (.003 per cent) showed that this material can be used successfully reduce set and not cause as severe injury as described above. In fact, very little visible injury resulted from application at this concentration. When used with a wetting agent (Vatsol K), this material significantly reduced set of Arkansas Black at .002 and .001 per cent concentrations and caused no visible injury to the tree.

Naphthalene acetamide may have value as a spray to reduce set, since sprays of .008 per cent concentration applied in the "on" year have reduced set without visible injury to the tree.

Boron in the form of borax would also appear to have definite possibilities since concentrations of .5 and 1.0 per cent reduced set and did not cause visible injury. Tests have not been as extensive on this material as those mentioned above. Nevertheless, it has been effective in one test and other work has indicated that, if necessary, even greater concentrations can be used without injuring the trees.

It would appear as though indole-acetic acid and indole butyric acid are of no value as a spray to increase set of Arkansas Black at the concentrations used in these tests. The above materials and indole propionic acid did not increase the set of Stayman Winesap.

Literature Cited

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Results of Thinning Peaches with Elgetol and Switches[1]

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In order to obtain a satisfactory size and quality, peaches have to be thinned, if the fruit set is heavy. This is commonly done by hand, which, due to the present (1944) scarcity of labor is difficult to accomplish. Another, less laborious procedure of thinning the crop, therefore, is urgently required.

The present is a preliminary report on the results of thinning Elberta peaches, while still in bloom, with Elgetol (20 per cent sodium salt of dinitro-ortho-cresol) and by means of elm switches. Either of these thinning practices, while not original, are still new. Batjer and Moon (1) seem to have thinned Elberta peaches properly with Elgetol at .1 to .2 per cent concentration applied when 95 per cent of the blossoms were open but have stated that a .4 per cent spray was too strong. In popular literature it has been reported that peach growers in Georgia and adjoining regions are practicing to some extent an economical method of thinning peaches in the bloom by means of brush brooms or switches.

For our experiments, vigorous, well-pruned, 7-year-old Elberta trees were used. Because of winter killing of flower buds, they had not borne a crop in the preceding two years. The bloom was very heavy in 1944. A mild frost (28 degrees F) occurred two days before the treatments were given, but injury to the flowers (pistils) was insignificant. All spraying, by means of standard equipment, and brush thinning were done on the same day, which was cool and cloudy. For spraying, Elgetol was used at concentrations of .0625 to .5 per cent. For brush thinning, elm twigs, secured locally, were tied two to four to a stick to form a convenient loose broom. The time of thinning the flowers with such switches was 10 to 15 minutes per tree. Spraying, of course, was much faster and, therefore, required less labor. Two representative limbs on eight trees of each treatment were tagged for flower and fruit counts. As the trees in the row used for switch thinning were somewhat larger than those used for spraying, a different more comparable control row was selected — hence, a separate controls for each experimental group. The total yields of all trees under consideration were secured at harvest time when the fruit was graded.

An observation made about two months after the flowering period, when the final fruit set was recorded, showed that trees which had received the Elgetol spray at .25 and .5 per cent concentrations and those that had been switch-thinned had a noticeably better foliage (larger and greener leaves) than the corresponding controls. This may have an influence on subsequent flower bud formation and fruit production of these trees.

The results, presented in Table I, show that Elgetol, at all concentrations, reduced the average yield of fruit per tree, but not exactly in proportional order. When used at the strengths of .0625 and .125

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TABLE I—RESULTS OF THINNING ELBERTA PEACHES WITH ELGETOL AND SWITCHES. CAMPBELL EXPERIMENTAL ORCHARD, MISSOURI, 1944

No. of Trees	Treatment	No. of Flowers Counted	No. of Fruit Set	Per Cent Fruit Set	Average Yield (Bushels) Per Tree	Average Yield (Bushels) Per Acre (70 trees)	Remarks on July 7 Observation
			Spray Thinning				
13	Controls—not thinned	5,516	681	12.3	4.9	343	Too many fruit
15	Elgetol .0625 per cent	6,363	673	10.6	4.3	301	Not thinned enough
13	Elgetol .125 per cent	5,903	646	10.9	4.3	301	Not thinned enough
15	Elgetol .25 per cent	7,695	451	5.9	3.8	266	Thinned right
14	Elgetol .5 per cent	12,883	438	3.4	4.0	280	Thinned right
			Switch Thinning				
14	Controls—not thinned	6,413	544	8.5	5.5	385	Too many fruit
14	Switch thinning	10,271/4,687*	297	2.9	6.1	427	Thinned right

*Before and after thinning.

per cent, the crop did not appear to be thinned enough, but at .25 and .5 per cent, thinned right. Switch thinning, as regards fruit production, was more successful, since the per tree yield was increased considerably due primarily to an augmented size of the fruit (Table II).

TABLE II—GRADE DISTRIBUTION AND GROSS INCOME OF ELBERTA PEACHES THINNED WITH ELGETOL AND SWITCHES, 1944

Treatment	Percentage of Crop in Each Size Group: Over 2½ Inches	2-2½ Inches	Under 2 Inches	Relative Gross Income (Dollars): Per Tree	Per Acre
		Spray Thinning			
Controls—not thinned	10.2	82.5	7.3	14.77	1,033.90
Elgetol .25 per cent	20.0	75.8	4.2	11.70	819.00
Elgetol .5 per cent	32.6	65.9	1.5	12.62	883.40
		Switch Thinning			
Controls—not thinned	13.2	84.2	2.6	16.79	1,175.30
Switch thinned	42.0	55.9	2.1	19.52	1,366.40

It was thought of interest to ascertain the grade distribution and to calculate the actual gross income from fruit of the properly thinned trees. This information is given in Table II. It will be noted that the size of fruit, when judged by the increase in percentage of the crop made up of specimens over 2½ inches in diameter, was improved quite conspicuously as a result of bloom thinning. The relative gross income, per tree or acre, was not so satisfactory, however. It was less from the Elgetol sprayed trees than the corresponding controls, but appreciably more from the switch thinned trees. Improvement in size, as a result of thinning, must likewise lead to an increase in volume of the total yield. This rather "poor showing" from spraying

was due in a large measure also to the fact that the difference in price between large and small fruit was not very great under the existing marketing scheme (1944). While a "ceiling" was set for the better (large) fruit, there was not a correspondingly low enough "floor" for the poorer (small) peaches. Extreme drough, that prevailed during June and July, may have had also a bearing on the size of these peaches and income from the crop.

Conclusion

The results would seem to indicate that peaches may be thinned successfully by thinning the bloom with an appropriate spray, such as Elgetol, or by knocking off a desirable amount of the flowers with a convenient broom or switch. Both methods certainly merit further study.

Literature Cited

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Seasonal Changes in the Ascorbic Acid Concentration of Florida Grapefruit

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Introduction

During recent years much interest has been shown in the nutritive values of foods, as well as in the factors affecting these values. In part, at least, this increasing interest has resulted from the chemical identification of some of the common vitamins and the development of accurate and rapid methods for determining the vitamin content of various foods and food products.

The information reported here is on the ascorbic acid concentration in grapefruit (*Citrus paradisi* Fad.), and has been assembled from data presented in a more comprehensive paper in process of publication (3) dealing with the many factors that influence quality in that fruit. Because of the importance of this vitamin in human nutrition, it seems especially desirable to note the effects on the ascorbic acid concentration of such factors or conditions as: (a) Maturity and ripeness of the fruit, (b) seasonal variation within and among groves, and districts, (c) varieties and rootstocks, and (d) spraying of trees and fruit with lead arsenate.

Material and Methods

The present study covered four seasons, 1939–40, 1940–41, 1941–42, and 1942–43. Analyses were made at 4-week intervals on Marsh and Duncan varieties of grapefruit. The study included analyses of fruit from ten different groves of Marsh grapefruit on rough lemon rootstock, from six of Marsh on sour orange, from eight of Duncan on rough lemon, and from six of Duncan on sour orange.

In addition numerous tests were made to determine the effects of lead arsenate spray on the ascorbic acid concentration in Marsh and Duncan varieties. Samples were taken at regular intervals from 27 different plots of trees sprayed with lead arsenate and from 27 comparable unsprayed plots. The spray was applied in July, many weeks prior to commercial harvest, at the rate of one pound of lead arsenate to 100 gallons of water. In order to include fruit in various stages of maturity and ripening, the analyses were started about the last week in August and continued until the middle of May of each season.

Experimental plots in commercial groves were selected so as to include groves located in the central ridge district, where the soils are usually low in organic matter, in the east and west coast districts, where the soils have a higher organic-matter content, and in the Homestead-Rockdale district, where the soils are very rocky.

In each of these districts the plots were made up of Marsh and Duncan varieties on rough lemon and on sour orange rootstocks. The groves were in good physical condition and had been supplied with ample amounts of fertilizers.

The samples were taken to the laboratory at Orlando immediately after they were picked and were placed in storage at 32 degrees F until tested. Each sample consisted of 60 or more grapefruits picked at random from the 15 to 25 trees. In addition to ascorbic acid, other determinations were made on the fruit and juice (3).

The juice was extracted from the fruit by hand squeezing and then strained through cheesecloth in order to remove seeds and pulp. Aliquots of this composited juice were used in the determination of ascorbic acid.

Determinations for ascorbic acid concentration were made by the method described by Bessey and King (1), and consisted essentially in the titration of grapefruit juice with a solution of freshly prepared sodium 2,6-dichlorobenzenoneindophenol (2,6-dichlorophenolindophenol) which had been standardized against fresh commercial crystalline ascorbic acid.

The average ascorbic acid concentration for the season was obtained by averaging the results obtained for the individual groves according to picking periods, and these findings are shown in Tables I and II. Detailed information is presented in another publication (3).

Results

The results showed that Florida grapefruit from various sources has high antiscorbutic properties. The average ascorbic acid concentration (milligrams per milliliter of juice) of Marsh and Duncan fruits grown on rough lemon and sour orange rootstocks is shown in Table I. The highest concentrations were always found in immature grape-

TABLE I—Seasonal Changes in the Average Ascorbic Acid Concentration per Milliliter of Grapefruit Juice in Marsh and Duncan Grapefruit on Rough Lemon and Sour Orange Rootstocks. 1939–43

Season	Aug 25 Sep 2 (Mgs)	Sep 25–30 (Mgs)	Oct 23-28 (Mgs)	Nov 20 25 (Mgs)	Dec 18-23 (Mgs)	Jan 15–20 (Mgs)	Feb 12–17 (Mgs)	Mar 11-16 (Mgs)	Apr 7-13 (Mgs)	May 6–11 (Mgs)
Marsh on Rough Lemon										
1939–40	.45	.41	.38	.37	.38	.35	.36	.32	.32	.32
1940–41	.47	.45	.44	.43	.43	.40	.38	.38	.37	.35
1941–42	.53	.48	.44	.41	.37	.36	36	.35	35	.33
1942-43	.49	.42	.41	.39	.38	.37	.36	.35	.34	.32
Marsh on Sour Orange										
1939–40	.49	.45	.42	.40	.40	.40	.39	.38	.37	.37
1940–41	.50	.49	.48	.44	.44	.38	.38	.37	.36	.34
1941–42	.56	.48	.46	.43	.40	.37	.37	.37	.37	.36
1942–43	.62	.51	.47	.44	.42	.42	.42	.42	.40	.38
Duncan on Rough Lemon										
1939–40	.43	.40	.40	.38	.38	.38	37	35	.35	.36
1940–41	.42	.42	.42	.41	.42	.40	.39	.38	.37	.36
1941–42	.47	.45	.44	.41	.39	.38	.37	.37	.36	.35
1942–43	.50	.45	.44	43	.42	.41	.40	41	.40	.38
Duncan on Sour Orange										
1939–40	.44	.41	.40	.40	.40	.40	39	.35	.36	.38
1940–41	46	.44	.45	.44	.43	.40	.39	.36	.36	,34
1941–42	.52	.45	.44	.42	.39	.39	.37	.37	.34	.33
1942–43	.53	.47	.45	.44	.43	.43	.42	.42	.40	.38

fruit. As the fruit ripened, the concentration gradually decreased. Lowest values were found late in the season in very ripe fruit. However, because the volume of juice increased as the fruit ripened, the total ascorbic acid per grapefruit also tended to increase during this period.

Regardless of the source of the grapefruit, the variation in its ascorbic acid concentration was comparatively small at any particular sampling period. This is also indicated by the small differences found at comparable periods in different seasons (see Table I). Those differences that occurred are of interest but are probably not of nutritional significance.

The results obtained on the ascorbic acid concentration are in fairly close agreement with those reported by French and Abbott (2). These investigators analyzed oranges and grapefruit grown in the north, central, and east coast citrus districts of Florida, and reported that the range of values for vitamin C seemed to bear no relation to the district where the fruit was produced. They concluded that this indicated that climatic or geographic influences within the section studied were not factors of importance. Certain other factors, however, such as the exposure of the fruit to sunlight (4, 5, 6) and conditions making for a low nitrogen level at harvest (7) have been reported as influencing the ascorbic acid concentration in oranges and grapefruit.

The influence of the rootstocks on the concentration of ascorbic acid was very slight. On the basis of milligrams of ascorbic acid per milliliter of juice, the amount was slightly greater when Marsh and Duncan fruits were on sour orange than on rough lemon. In ripe grapefruit very little difference was found in the concentration of ascorbic acid of Marsh fruit on sour orange and the Duncan on rough lemon and on sour orange rootstock; however, a lower average ascorbic acid concentration was found in the Marsh grapefruit on rough lemon (Table I).

The data (Table II) show a very slightly higher ascorbic acid concentration in the fruit sprayed with lead arsenate than in the unsprayed fruit, the differences being so slight as to be considered negligible. These results are of special interest since Nelson and Mottern (8) reported that the vitamin C content in oranges from trees sprayed with lead arsenate was considerably lower than that in oranges from unsprayed trees of the same variety and the same degree of maturity.

As with fruit from unsprayed trees (Table I), the highest average concentration of ascorbic acid was found in immature Marsh and Duncan grapefruit, while lower values were found late in the season in very ripe fruit. The influence of rootstocks on the concentration of ascorbic acid in the sprayed fruit (Table II) was similar to that already reported for the unsprayed (Table I).

Summary

Extensive studies were conducted during four seasons, 1939 to 1943, to determine the ascorbic acid concentration in the fruits of the Marsh and Duncan varieties of grapefruit.

Florida grapefruit is characteristically high in ascorbic acid concentration, regardless of variety, location of grove, rootstock, cultural practices, or seasonal conditions. The concentration varies chiefly with the maturity of the fruit, the greatest concentration being found in

TABLE II—Effect of Lead Arsenate Spray on the Average Ascorbic Acid Concentration per Milliliter of Grapefruit Juice at Different Picking Periods, 1939–43

Treatment	Aug 25 Sep 2 (Mgs)	Sep 25–30 (Mgs)	Oct 23-28 (Mgs)	Nov 20–25 (Mgs)	Dec 18-23 (Mgs)	Jan 15–20 (Mgs)	Feb 12–17 (Mgs)	Mar 11-16 (Mgs)	Apr 7–13 (Mgs)	May 6–11 (Mgs)
Marsh on Rough Lemon										
Unsprayed	.49	.42	.41	.39	.38	.37	.36	.35	.34	.32
Sprayed	.50	.43	.41	.41	.39	.38	.37	.36	.34	.32
Difference	+.01	+.01	.00	+.02	+.01	+.01	+.01	+.01	.00	.00
Marsh on Sour Orange										
Unsprayed	.62	.51	.47	.44	.42	.42	.42	.42	.40	.37
Sprayed	.62	49	47	46	.44	.42	.42	.43	.39	.37
Difference	.00	−.02	.00	+.02	+.02	.00	.00	+ 01	−.01	.00
Duncan on Rough Lemon										
Unsprayed	.50	45	.44	.43	.42	.41	.40	.41	.40	.38
Sprayed	.49	.46	.45	.14	.43	.42	.42	42	.40	.38
Difference	−.01	+.01	+.01	+.01	+.01	+.01	+.02	+.01	.00	.00
Duncan on Sour Orange										
Unsprayed	.53	.46	.45	.44	43	.43	.42	.42	.40	.38
Sprayed	.52	.46	.44	.44	.43	43	.42	.42	.41	.39
Difference	−.01	.00	− 01	.00	00	.00	.00	.00	+.01	+.01

+ indicates that ascorbic acid in sprayed fruits was greater; − than it was less.

the juice of immature fruit. As the fruit ripened, however, the gradual decrease in concentration of the ascorbic acid was more than balanced by the increased volume of juice per fruit, so that the total ascorbic acid per fruit was greatest in ripe fruit.

The variation in the ascorbic acid concentration within and among groves, as well as among districts, was comparatively small and irregular, the differences probably being not significant from the standpoint of the nutritional value of the fruit.

The rootstock on which the grapefruit was grown had but slight influence on the ascorbic acid concentration. However, slightly lower average ascorbic acid concentration was found in Marsh grapefruit on rough lemon rootstock.

Spraying the trees and fruit in the summer with one application of lead arsenate at the rate of one pound to 100 gallons of water had no marked effect on the ascorbic acid concentration in the juice of Marsh or Duncan grapefruit.

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The Effects of Differential Nitrogen Treatments in the Orchard on the Keeping Quality of McIntosh Apples[1]

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Introduction

The McIntosh apple variety seems to react adversely in certain respects to large additions of nitrogenous fertilizers even though growth and yields may be increased. This study was conducted to investigate the effects of differential nitrogenous fertilizer treatments in the orchard on certain pre-storage and storage characteristics of McIntosh fruits. Most investigations (2, 3, 4, 7, 8, 9, 11) have shown little or no effect of nitrogen applications on fruit firmness prior to or during storage. Several workers (5, 6, 13) have found reduced keeping quality as a result of nitrogen additions to certain varieties, however.

Methods

In all of the orchards studied the apple trees were grouped in sets of two or three (depending upon the number of fertilizer treatments) on the basis of tree size and annual growth before the start of the experiment. In the Losee orchard 10 pairs were used; in the Forrence orchard 17 groups of three trees each were used; in the other three orchards 20 groups of three trees each were used. This meant that the number of trees in each orchard receiving each treatment ranged from 10 to 20. Unless otherwise specified all the orchards were in sod. Fertilizer applications were made in April of each year.

A sample of 50 fruits was taken from each tree in every treatment at harvest time and placed in storage at 32 degrees F. The apples were picked at random on the outsides of the trees in positions well exposed to light.

Within 2 or 3 weeks after being placed in storage samples of 10 fruits each were taken from each tree lot for a determination of ground color, firmness, and soluble solids content. These determinations appear in the tables of data as being made "at harvest". About the first of April the remaining 40 fruits from each tree lot were removed from storage for an examination of ground color, firmness, brown core, and scald. The data in Tables I and II contain only the means for all trees in each treatment.

The surface area of the fruits was computed from the weights of the 50 fruit samples from each tree according to the method of Baten and Marshall (1).

The leaf samples for total (Kjeldahl) nitrogen were taken in July of the year for which they are reported. Fifty median shoot leaves were picked at random from the outside of each tree in the experi-

[1]This report covers a phase of a larger study on the effects of differential nitrogen treatments on the behavior of the McIntosh tree and fruit being conducted by the junior author.

mental plots. Thus the nitrogen analyses reported in Tables I and II represent the means of from 10 to 20 samples for each treatment.

RESULTS — LOSEE ORCHARD

This orchard in Dutchess County, New York, is on Hoosic gravelly, loam soil. The trees were about 26 years old when this experiment was started. The two differential treatments of 8 pounds and 4 pounds of ammonium sulfate per tree had been given these trees for 2 years prior to the start of this study.

In 1942 there was a good bloom and set of fruit on all experimental trees. The high nitrogen trees had darker green foliage, more shoot growth, and higher yield than the low nitrogen trees. In 1943 there was only a moderate bloom and a relatively light crop on both treatments. Though the high nitrogen trees were in only fair vigor, they had a higher yield and higher leaf nitrogen than the low nitrogen trees. The low nitrogen trees had light green leaves and made very little terminal growth in 1943.

Data obtained at harvest and after storage appear in Tables I and II.

TABLE I—EFFECT OF NITROGEN TREATMENT ON McINTOSH FRUITS, 1942

Ammonium Sulfate (Pounds)	Leaf Nitrogen (July) (Percent Dry Weigh)	At Harvest 1942			After Storage—April 1, 1943			
		Firmness (Pounds)	Ground* Color	Soluble Solids (Per Cent)	Firmness (Pounds)	Ground* Color	Brown Core (Per Cent)	Scald (Per Cent)
				Losee (Hudson Valley)				
8.0	—	—	—	—	10.64 ±.08	2 77	42.60 ±3.1	0
4.0	—	—	—	—	10.00 ±.05	1.88	46.44 ±3.9	0
				Clark (Hudson Valley)				
12.0	2.43	14.68 ±.19	2.44 ±.07	11.61 ±.06	10.39 ±.14	2.48	70.18 ±3.9	15.00 ±2.0
8.0	2.09	14.74 ± 17	2.38 ±.07	11.77 ±.06	10 77 ±.09	2.55	72.19 ±2.15	13.55 ±2.1
4.0	1.78	15.51 ±.13	2.63 ± 07	12.18 ±.05	11.30 ±.09	2.96	55.91 ±2.42	17.46 ±2.9
				Kappel (Western New York)				
7.5	2.39	11.87 ±.19	2.21 ±.06	12 18 ±.08	10 1 ±.10	2.25	38.2 ±2.80	26.0 ±2.7
5.0	2.35	11.58 ±.16	2.53 ±.08	12.22 ±.05	9.9 ±.06	2.23	27.9 ±2.51	9.0 ±1.2
2.5	2.32	11.58 ±.20	2.62 ±.05	12.20 ±.03	10.6 ±.12	2.84	27.1 ±1.88	9.9 ±2.6
				Shannon (Western New York)				
7.5	2.17	10.94 ± 14	2.42 ± 06	11.61 ±.09	10.09 ±.10	2.60	34.50 ±2.2	15.20 ±4.0
5.0	2.06	11.29 ±.14	3.06 ±.09	11 48 ±.08	10.00 ±.09	2.99	24.30 ±3.7	16.77 ±5.7
2.5	1.95	11 30 ±.18	2 03 ±.06	11.49 ±.08	10 91 ±.10	3.25	16.60 ±2.0	23.18 ±6.3

*Expressed on a scale of 1 to 4, 1 represents green and 4 full yellow ground color.

1942 Results:—No data were obtained in this orchard at harvest in 1942. The data after storage (Table I) indicate that the larger nitrogen application resulted in significantly softer and greener fruit. There was no difference in the amount of brown core or scald.

1943 Results:—Data after harvest (Table II) show that the larger nitrogen treatment resulted in significantly softer and greener fruit. There was no difference in soluble solids. After storage the fruits from the high nitrogen trees were softer and greener than those from the low nitrogen trees, but they had not softened faster in storage. There

TABLE II—EFFECT OF NITROGEN TREATMENT ON McINTOSH FRUITS, 1943

Ammonium Sulfate (Pounds)	Leaf Nitrogen (July) (Per Cent Dry Weight)	At Harvest 1943				After Storage—April 1, 1944			
		Firmness (Pounds)	Ground* Color	Surface Area (Sq Ins)	Soluble Solids (Per Cent)	Firmness (Pounds)	Ground* Color	Brown Core (Per Cent)	Scald (Per Cent)
					Losee (Hudson Valley)				
8.0	1.99	15.8±.11	2.47±.08	24.15	13.8±.10	10.4±.19	2.1±.14	65.9±2.9	13.4±1.27
4.0	1.83	17.1±.02	2.82±.11	23.00	13.6±.09	10.7±.71	3.0±.07	62.4±4.9	11.6±1.16
					Clark (Hudson Valley)				
12.0	2.14	14.0±.14	2.32±.06	24.02	12.0±.06	10.4±.14	2.3±.06	68.9±2.8	26.5±1.6
8.0	2.06	15.2±.11	2.32±.06	23.90	12.1±.06	11.0±.15	2.5±.06	65.7±2 3	28.5±2.0
4.0	1.93	14.7±.16	2.62±.04	23.64	12.0±.09	11.3±.24	2.8±.11	66.8±2.4	23.6±1.65
					Kappel (Western New York)				
7.5	2.42	16.6±.14	2.27±.04	23.52	12.0±.05	10.4±.10	2.2±.06	55.1±3.5	8.1±1.7
5.0	2.39	16.6±.46	2.39±.03	23.90	12.1±.06	10.6±.10	2 5±.07	47.3±3.3	8.1±1.6
2.5	2.27	17.3±.08	2.74±.08	23.27	12.0±.06	11.2±.16	3.3±.11	40.2±2.8	9.51±2.09
					Shannon (Western New York)				
7.5	2.18	15.9±.07	2.15±.03	24.92	11.3±.05	9.9±.09	2.2±.07	52.7±2.5	22.2±3.9
5.0	2.04	16.1±.03	2.36±.03	24.55	11.6±.07	10.4±.10	2 4±.12	32.4±3.5	35.5±3.5
2.5	1.84	17.1±.14	2.81±.01	23.64	11.9±.01	10.9±.10	3.4±.04	18.8±3.9	49.4±2.37
					Forrence (Champlain Valley)				
10.0	2.23	16.2±.11	2.35±.02	22 80	11.7±.09	10.0±.17	2.8±.16	75.7±2.5	0.55±.36
5.0	2.16	16.3+.13	2.43±.04	23.50	11.7±.18	10.2±.15	3.0±.09	75.6±2.8	0
0.0	1.77	17.8±.15	3.0±0	21.94	12.0±.07	10.8±.13	3.7±.10	55.3±3.4	0

*Expressed on a scale of 1 to 4; 1 represents green and 4 full yellow ground color.

was a good correlation between leaf nitrogen and ground color and firmness (Figs. 1 and 2). There were no differences in brown core or scald.

RESULTS — CLARK ORCHARD

This orchard in Ulster County on Cossayuna gravelly loam soil was 17 years old at the start of this study. In the year prior to the start of differential treatments all trees had received 2 pounds of Uramon (42 per cent nitrogen) broadcast under the spread of the branches. The sod was composed of a dense growth of quack grass. At the start of this study in 1942 all trees were at a low nitrogen level as indicated by leaf nitrogen, leaf color and fruit color. The differential nitrogen treatments were 12, 8, and 4 pounds of ammonium sulfate per tree.

In 1942 there was a very light set of fruit on all trees, and yield differences were not apparent. Because of the light crop all fruits tended to be large. There was a good correlation of leaf nitrogen content with fertilizer treatment (Table I).

In 1943 there was a response in yield, growth, and leaf nitrogen to progressive increases in nitrogen application and the yields on all trees were more nearly normal than the previous year.

1942 Results:—At harvest time there was no difference in firmness of fruits from the large and medium applications of nitrogen but the low nitrogen treatment resulted in firmer fruit than the other two ap-

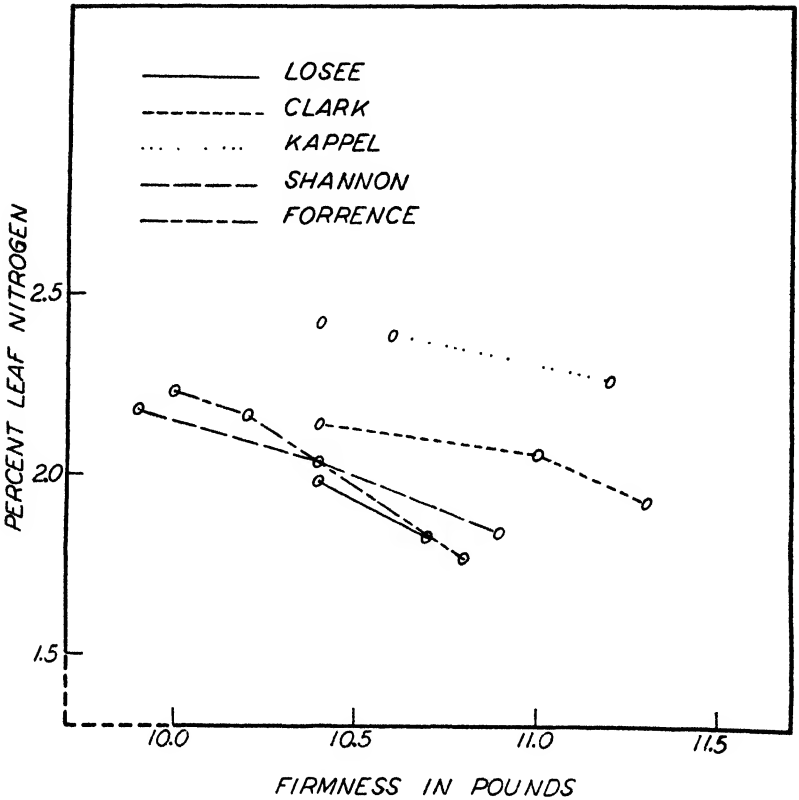

FIG. 1. Relation of fruit firmness of McIntosh apples (after storage) and leaf nitrogen (sampled in July) in five New York orchards in 1943–44.

plications (Table I). The low nitrogen application resulted in a better development of yellow ground color than the medium and large applications, but there was no difference between the medium and large applications. Soluble solids were higher in the low nitrogen treatment than in the others.

After storage, fruit firmness decreased progressively as the nitrogen application and leaf nitrogen increased. Similar results are shown in the ground color data. There was no difference in the amount of brown core in the large and medium applications but the low nitrogen trees had less of this trouble than the other two treatments. There were no differences in scald.

1943 Results:—In the examination of the fruit at harvest time (Table II) it was apparent that the fruits from low nitrogen trees were firmer than those from the high nitrogen trees, but the medium application resulted in the firmest fruits. The fact that the medium nitrogen fruits were firmer than those from high nitrogen trees is in line with other data but the fact that they were firmer than the low nitrogen

fruits presents a discrepancy. There were no differences in ground color in the high and medium nitrogen fruits but the fruits from the low nitrogen treated trees had more fully developed ground color than resulted from the other two treatments. There were no differences in the amount of soluble solids in the fruit.

Examination after storage revealed that the fruits were progressively softer with increasing applications of nitrogen and increasing leaf nitrogen although the difference between the medium and low applications is not statistically significant. A reduction in development of ground color was noted with increasing nitrogen applications and increasing leaf nitrogen. There were no differences in brown core or scald.

Results — Kappel Orchard

This Wayne County, New York, orchard on Ontario loam was 13 years old at the start of the experiment. The trees were at a low nitro-

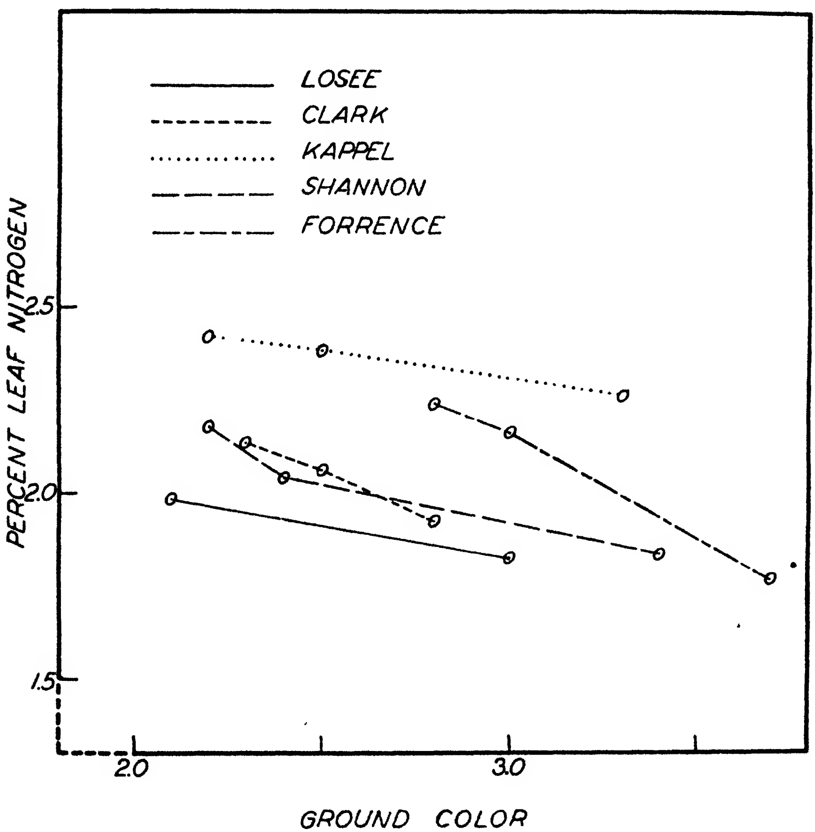

Fig. 2. Relation of ground color of McIntosh fruits (after storage) and leaf nitrogen (sampled in July) in five New York orchards, in 1943–44 (ground color represented on a scale of 1 to 4; 1 indicates green and 4 full yellow ground color).

gen level in 1941 as evidenced by yellow leaves and small, red fruit. During the 1942 season this orchard which had been in sod was given two cultivations. No cultivations were made in 1943 and the sod became re-established. The differential nitrogen treatments consisted of 7½, 5, and 2½ pounds of ammonium sulfate per tree in 1942 and 1943.

During the 1942 season the set of fruit was light and there was very little difference in leaf nitrogen in the three treatments. Apparently the cultivations released some nitrogen to all the trees because leaf nitrogen was high and leaf color was dark green on all trees. However, the yield was low on all trees, presumably as a result of a light bloom and poor set. During 1943 the set of fruit was light perhaps because of poor pollination weather, and yield differences were small although there was progressively more leaf nitrogen with increasing nitrogen application.

1942 Results:—At harvest there seemed to be no significant differences between treatments in firmness of fruit (Table II). Fruits from the low nitrogen treatment were somewhat more yellow than those from the other two treatments. There were no differences in soluble solids.

After storage the fruits from the low nitrogen treatment were somewhat firmer than the other two lots but there was no difference between the large and medium applications. This held true for ground color data also. There seemed to be somewhat more brown core and scald on the fruit from the large application of nitrogen but there were no other differences.

It is not surprising that differences were not more apparent this year in this orchard in view of the fact that there were no differences in leaf nitrogen or yield. Apparently the cultivations, or the very light yield on all trees (or both) had more or less equalized the storage characteristics of these fruits.

1943 Results:—There was no difference between the large and medium applications of nitrogen in the firmness of the fruit after harvest although the fruits from the low nitrogen trees were firmer than those from the other two treatments (Table I). This same trend was noted in the ground color. There were no differences in soluble solids.

In the examination after storage the fruits were progressively softer with increasing applications of nitrogen and increasing leaf nitrogen, although the difference between the large and medium amounts was not significant. This same trend occurred in development of ground color. There seemed to be progressively more brown core with increasing nitrogen applications but the only significant difference was that between the large and the small application. There were no differences in scald.

Results — Shannon Orchard

This Wayne County, New York, orchard on Dunkirk fine sandy loam was 20 years old at the start of this study. The trees were in a sparsely growing sod and had been fertilized with two pounds of

Uramon (42 per cent nitrogen) per tree during the year prior to the start of this investigation. The differential nitrogen treatments were 7½, 5, and 2½ pounds of ammonium sulfate per tree in 1942 and 1943. In 1942 the differential nitrogen treatments were reflected in leaf nitrogen and color of fruit but not in yield. In 1943 leaf nitrogen content was higher with increasing amounts of nitrogen fertilizer. In 1943 there was no significant difference between the yields of the high and medium nitrogen trees but the low nitrogen trees yielded significantly less than the others.

1942 Results:—At harvest the high nitrogen application resulted in the softest fruits (Table I). The medium application resulted in firmer fruits than the large application but there was no difference between the medium application and the small application. There was a good correlation between leaf nitrogen and firmness. The medium application of nitrogen resulted in the best development of ground color. The fact that the low nitrogen treatment resulted in the poorest development of ground color is at odds with the other results in this study and this observation did not hold in the same fruit after storage. There were no significant differences in total soluble solids in these fruits at the time of harvest.

After storage the firmness of the fruit from the low nitrogen trees was considerably greater than that of fruit in the other two treatments. There was no difference between the large and medium applications with regard to firmness after storage. There was also progressively better development of ground color with decreasing amounts of nitrogen. There seemed to be no difference in brown core in fruit from the high nitrogen treatment. There was slightly more scald in the low nitrogen fruits but the difference was not significant.

1943 Results:—At the examination after harvest it was apparent that increasing amounts of leaf nitrogen were associated with a reduction in fruit firmness, although the difference between the large and medium applications was not significant. This same trend was noted for ground color development. There was a decreasing amount of soluble solids in the fruit with increasing amounts of leaf nitrogen.

Fruit examined after storage revealed that increasing amounts of leaf nitrogen were associated with softer fruit (Fig. 1). These differences in firmness do not mean there was an increased rate of softening in storage but merely reflect a persistence of differences shown when the fruits were picked. This effect of nitrogen was also noted in ground color development although the difference between the large and medium applications is not significant (Fig. 2). Increasing amounts of nitrogen in the orchard seemed to result in increasing amounts of brown core and decreasing amounts of scald. All these differences seemed to be significant.

Results — Forrence Orchard

This Clinton County, New York, orchard on Dover loam soil was 17 years old at the start of this study. The trees were growing in a heavy sod and had been fertilized in 1941 with 5 pounds of ammonium

sulfate per tree. The differential nitrogen treatments were started in 1942 and repeated in 1943 but only the 1943 fruit was stored in this study. The amounts of ammonium sulfate used per tree each year were 10, 5, and 0 pounds.

In 1942 and 1943 the differential nitrogen treatments were reflected in differences of leaf nitrogen, fruit color, and yield.

1943 Results:—Data taken after harvest (Table II) show that the no nitrogen trees produced fruit that was firmer than fruit from moderate or high nitrogen treated trees. The difference between the latter two treatments was not significant. Increasing amounts of leaf nitrogen were associated with decreased development of ground color. Fruits from the no nitrogen trees had somewhat more soluble solids than fruit from the other two treatments.

After storage the same relationships existed in fruit firmness and ground color as after harvest (Figs. 1 and 2). Differences between the medium and high nitrogen treatments were not significant. There seemed to be significantly less brown core on the no nitrogen treated fruit but the difference between the medium and large application was not significant. There were no differences in scald.

Discussion

In this study of five New York orchards there is a strong suggestion that fruit firmness is decreased by nitrogen applications. In some cases increased nitrogen applications in the orchard did not result in decreased firmness. In these same cases, these increased applications usually did not result in increased leaf nitrogen. For example, in 1942 in the Kappel orchard the effects of the nitrogen treatments seemed to be masked by either the light crop or the two cultivations given the orchard. Leaf nitrogen differences were not evident in this case either.

Differences in firmness were more evident in the fruits after storage than at harvest time. This does not mean that the nitrogen applications increased the softening rate in storage. These more apparent differences may more likely be attributed to the larger number of fruits sampled after storage. Differences after storage usually reflected differences that persisted during storage. A preliminary study of the effect of nitrogen level on respiration rate of fruits from the Shannon orchard held at a high temperature indicate a faster respiration rate at the higher nitrogen levels. If there were differences in respiration of these fruits during 32 degrees F storage they were not reflected in the softening rates.

The question arises as to why nitrogen increases often resulted in softer fruit. It is true that in general the nitrogen applications resulted in larger fruits (Table II) and it is well known that large fruits are usually softer than small ones. In Table II it may be seen that there is a good inverse correlation between leaf nitrogen and firmness but the correlation between size and firmness is not so good. This point can only be clarified by determining the firmness of fruits of the same size from trees at different nitrogen levels.

There is a better correlation between leaf nitrogen and ground

color development than there is between actual nitrogen additions and ground color development. A high leaf nitrogen content was usually associated with greener ground color (Fig. 2).

In many cases there was no effect of nitrogen additions on the soluble solids content of the fruits. Where significant differences were apparent, however, there were less soluble solids with the larger applications of nitrogen.

The effect of nitrogen additions on the development of brown core during storage was not consistent in all orchards. Where there were differences, however, there was a strong suggestion of increased brown core with the higher nitrogen applications. This is in contrast with the work of Smith (11) but it was not clear from his work that there were actual nitrogen differences within the trees.

In four orchards there was no effect of nitrogen additions on the development of scald during storage. In one orchard there was a strong suggestion of reduced scald with the higher nitrogen levels in the leaves. Reduced scald incidence with nitrogen applications is not in line with most observations on this point (4, 6) but Savage (10) has noted less scald on Cortland with higher nitrogen levels. In an independent study at Cornell (12) it was found that high nitrogen levels did not increase scald on either McIntosh or Rhode Island Greening. Surely certain storage factors are more important in determining the amount of scald than the nitrogen level of the trees with these particular varieties.

Summary

In this 2-year study in four orchards and a single year in a fifth orchard on the effect of differential nitrogenous fertilizer applications, the following general conclusions seem valid:—

Increases in the amount of nitrogen fertilizer seemed to result in decreased firmness of fruit at harvest time, but did not seem to stimulate increased rates of softening during storage.

Increases in the amount of nitrogen fertilizer seemed to result in a retardation of the normal development of yellow ground color.

There was not always a direct correlation between the amount of nitrogen applied and the effect on firmness or ground color but there was almost always an inverse correlation between leaf nitrogen and fruit firmness and ground color.

In general there was not any marked effect of differential nitrogen treatment on soluble solids in the fruits; but where there were significant differences, soluble solids were reduced by the higher nitrogen levels.

There was also a suggestion of increases in the amount of brown core after storage in some orchards with higher leaf nitrogen levels but there was not always a direct correlation with the amount of fertilizer applied to the trees.

In four orchards there was no effect of differential nitrogen treatments on the incidence of storage scald but in one orchard there was a strong suggestion of reduced scald with the larger nitrogen applications.

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The Vitamin C Content of Guavas[1]

By H. J. WEBBER, *University of California Citrus Experiment Station, Riverside, Calif.*

THE extraordinary richness of guava fruits in vitamin C (ascorbic acid) has been emphasized recently by Golberg and Levy (3 and 4), Boyes and de Villiers (2), Waddington and Cist (7), and Webber (8). Some additional data that have accumulated at this Experiment Station are suggestive and valuable, though of preliminary nature.

DISTRIBUTION OF VITAMIN C IN THE FRUIT

The results of several investigations indicate that the concentration of vitamin C in the guava fruit is not uniform but decreases gradually from the outside inward. Golberg and Levy (3) found that "The proportion of vitamin C in skin, outer pulp, and inner pulp may be as high as 12: 5: 1." Boyes and de Villiers (2) found similar variations in the concentration in the different parts, but their ratios were not so great: they were nearer to a ratio of 3: 2: 1 (per cents of total were 51, 32.3 and 16.6). Sinclair and Bartholomew, in analyses made at this Experiment Station, of varieties named by the writer, combined the skin with the outer flesh in their determinations but these may be compared with the quantities found in the inner pulp (see Table II). In all cases higher quantities of vitamin C were found in the skin and outer pulp than in the inner pulp, thus confirming the results of other investigators.

If, as seems evident, the percentage of vitamin C in the fruit gradually decreases from the surface inward, then a guava with a very thick outer flesh (a distinctly desirable character) might be expected to exhibit a proportionately lessened concentration of vitamin C for that portion of the fruit than a variety with thin outer flesh.

VARIATION IN VITAMIN C CONTENT OF DIFFERENT VARIETIES

Guavas have heretofore been propagated almost wholly as seedlings, and the published analyses of fruit have been mainly of samples from various trees after grading them according to color or shape. Such analyses serve to show the general richness of guavas in vitamin C but

TABLE I—ASCORBIC ACID CONTENT OF GUAVA VARIETIES
(Fresh Fruit, Peel and Pericarp Only)*

Guava Variety	Color of Flesh	No. Trees Sampled	No. Fruits Per Sample	Milligrams Ascorbic Acid Per 100 cc	Juice pH
Riverside	White	1	22	432	3.75
Volusia	White	1	34	472	3.73
Hart	White	1	14	653	3.70
Webber	Red	1	33	164	3.78
Rolfs	Red	1	7	971	3.85
Longped	Orange	1	17	346	3.62

*Quoted from F. M. Turrell in Webber (8).

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they do not furnish data sufficiently definite on which to base the selection of varieties. It is of primary importance to know what variations in vitamin C content exist in different varieties that are otherwise satisfactory for general culture and then to determine to what extent that content is modified by production under different climatic and cultural conditions.

Previous to the publication of the preliminary paper by Golberg and Levy (3), the writer had been studying the variations and types among guava seedlings grown at the California Citrus Experiment Station, from seeds of good sorts collected in many tropical countries. Some 30 different seedlings which represented a wide range of characters had been selected and named as varieties. It immediately became

TABLE II—Ascorbic Acid (Vitamin C) Content of Guava Varieties Grown in Riverside, California, in 1942

(Analyses by Dr. W. B. Sinclair and Dr. E. T. Bartholomew of the University of California Citrus Experiment Station)

I*	II**	III	IV	V	VI	VII
Variety and Source of Seed	Important Fruit Characters (See Footnote)	Date Picked in 1942	Number of Fruits	Degree of Maturity	Ascorbic Acid (Vitamin C) Mgs per 100 Gms Fresh Fruit	
					Outer Flesh (pericarp)	Inner Flesh or Core
Rolfs (Florida)	Weight 121 gms, L/D ratio 1.17, pink, sweet, early	Nov 13 Nov 13 Nov 13	5 5 5	Mature Mature Light green	284.9 352.4 273.5	193.1 214.7 159.4
Longped (Florida)	Weight 130 gms, L/D ratio 1.08, yellow, sweet, midseason	Nov 27 Nov 27	7 7	Mature Green hard	90.1 98.8	68.8 ——
Volusia (Florida)	Weight 149 gms, L/D ratio 1.13, white, sweet, midseason	Nov 30 Nov 30	6 8	Mature Green hard	161.0 129 7	94.7 ——
Hannah (Florida)	Weight 151 gms, L/D ratio 1 12, white, sweet, midseason	Dec 1 Dec 1 Dec 17	8 8 8	Mature Light green Mature	128.3 120.5 182.0	87.3 —— ——
Riverside (Florida)	Weight 205 gms, L/D ratio 1.02, white, sweet, midseason	Dec 4 Dec 4	8 8	Mature Light green	166.3 151.0	86.2 ——
Hart (Florida)	Weight 147 gms, L/D ratio 1 05, white, sweet, early medium	Dec 8 Dec 8	8 8	Mature Light green	168.6 148.2	100.6 ——
Florence (Florida)	Weight 131 gms, L/D 1.19, yellow, sweet, medium late	Dec 10	8	Light green to mature	159.6	——
Arrons (Florida)	Weight 141 gms, L/D ratio 1.12, yellow, sweet, late	Dec 15	8	Mature	161.4	81.2
Ehrhorn (Hawaii)	Weight 50 gms, L/D ratio 1.59, pink, subacid, very early	Nov 16 Dec 9	4 12	Light yellow Firm Mature	154.1 95.9	138.3 ——

*The varieties listed in column I are all selected seedlings grown and named at the California Citrus Experiment Station. Full descriptions have not yet been published. The source of the original seed is given in parentheses.

**Under each variety in column II there is given: 1, the average weight of fruit in grams; 2, the average L/D ratio, which is the ratio of length divided by diameter and indicates the average shape; 3, the color of flesh; 4, the taste, sweet or acid (sour); 5, the season of ripening at Riverside, California; early, indicating September–November; midseason or medium, October–December; and late, December–February.

TABLE II (*concluded*)

I*	II**	III	IV	V	VI	VII
Variety and Source of Seed	Important Fruit Characters (See Footnote)	Date Picked in 1942	Number of Fruits	Degree of Maturity	Ascorbic Acid (Vitamin C) Mgs per 100 Gms Fresh Fruit	
					Outer Flesh (pericarp)	Inner Flesh or Core
Marble (Hawaii)	Weight 37 gms, L/D ratio 1.00, white, sweet, midseason	Nov 16	15	Mature	253.6	249.5
		Dec 9	15	Green hard	211.2	——
		Dec 9	20	Mature	253.4	——
Herradura (Cuba)	Weight 69 gms, L/D ratio 1.51, white, acid, midseason	Nov 17	10	Mature	68.5	40.1
		Nov 17	10	Greenish yellow	48.0	——
		Dec 18	12	Mature	80.3	——
Esther (Cuba)	Weight 87 gms, L/D ratio 1.06, white, sweet, early	Nov 17	5	Mature	96.0	73.0
May (Cuba)	Weight 63 gms, L/D ratio 1.07, pink, sweet, early	Dec 10	8	Mature	110.9	——
Diaz (Mexico)	Weight 36 gms, L/D ratio 1.03, yellow, sweet, midseason	Nov 18	15	Mature	174.0	76.6
		Nov 18	15	Green hard	141.5	——
		Dec 22	12	Mature	219.1	——
Abaza (Egypt)	Weight 137 gms, L/D ratio 1.09, white, sweet, midseason	Dec 8	11	Mature	198.2	127.6
		Dec 8	11	Light green	175.6	——
Giza (Egypt)	Weight 91 gms, L/D ratio 1.10, pink, sweet, midseason	Nov 18	10	Mature	149.8	89.3
		Nov 18	10	Green hard	111.8	——
		Dec 22	16	Mature	195.0	——
Webber (Hawaii)	Weight 87 gms, L/D ratio 1.34, pink, sweet early medium	Dec 2	27	Mature	72.3	35.7
		Dec 2	16	Light green	67.6	——
Lucene (Hawaii)	Weight 96 gms, L/D ratio 1.16, pink, sweet, early medium	Dec 3	20	Mature	49.7	34.6
		Dec 3	16	Light green	49.2	——
Wilder (Hawaii)	Weight 110 gms, L/D ratio 1.29, pink, very acid, late	Dec 28	10	Mature	243.9	142.2
		Dec 28	10	Light Green	204.3	——

*The varieties listed in column I are all selected seedlings grown and named at the California Citrus Experiment Station. Full descriptions have not yet been published. The source of the original seed is given in parentheses.

**Under each variety in column II there is given: 1, the average weight of fruit in grams; 2, the average L/D ratio, which is the ratio of length divided by diameter and indicates the average shape; 3, the color of flesh; 4, the taste, sweet or acid (sour); 5, the season of ripening at Riverside, California; early, indicating September November, midseason or medium, October December; and late, December–February.

evident that the fruits of these seedlings, the mother plants of varieties, should be tested to determine their relative richness in vitamin C. Preliminary tests of a half dozen varieties were made for the writer by Dr. Franklin M. Turrell of the California Citrus Experiment Station in December, 1941, and are reported in Table I.

These estimates, reported as milligrams of ascorbic acid to 100 cc of expressed juice, indicate a wide range of variation in ascorbic acid concentration in different varieties.[2]

[2]It should be clearly understood that all of the analyses given in Tables I and II are analyses of fruits from single trees, the original mother tree seedlings, from which the varieties originated.

A second series of analyses of the ascorbic acid content of 19 different varieties grown at the California Citrus Experiment Station were made in 1942 by Dr. W. B. Sinclair and Dr. E. T. Bartholomew.[3] The results of these analyses are given in Table II. As descriptions of these varieties have not yet been published a few of the most important characters of each variety are given in column II of the table.

The following statement by Sinclair and Bartholomew relative to these analyses is quoted from their report dated January 5, 1943:

"The chemical determinations were made on fruits in the fully mature, in the light green immature, and a few in the green, firm stages . . . . With few exceptions, samples were analyzed the same day they were picked from the shrub . . . . In the mature fruit samples the outer flesh with peel and the inner flesh without seeds were used for analyses. In the immature fruit samples, only the outer flesh with peel was used for the analyses . . . .

"The vitamin C was determined in the acid extract of the tissue by the iodine titration method of Tillman as used by Stevens (6). Some of the vitamin C values obtained by this method were checked by titrating the extracts with KIO_3 in acid solution according to the method of Ballentine (1). Both of these methods gave values which were not significantly different.

"At the time these determinations were made, the dye (2:6-dichlorophenol-indophenol) was not available in the laboratory. Therefore, the comparison of that dye with the iodine method could not be made. It has been shown, however, by Boyes and de Villiers (2) that the vitamin C concentration in the acid extract of guava fruits as determined by these two methods gave sufficient agreement for all practical purposes. The vitamin C, as determined by the iodine method, represents the total free reducing substances in the acid extract, and according to the observations of Golberg and Levy (3), the vitamin C values determined by this chemical method are almost as great as those determined by the biological method.

"In the present studies the outer flesh of the fruit had a higher concentration of vitamin C than the inner flesh. This is in accord with the experimental results of published investigations (2). The distinctive feature of the data in Table II is the wide range in concentration of vitamin C in guava fruits of different varieties. In addition to varietal differences, variations due to differences in response to environmental conditions are undoubtedly large. Maynard (5) has noted that the concentration of vitamin C in tomatoes is greatly influenced by the number of hours of sunlight per day received by the plant. In addition to the length of daylight period, the light intensity alters the vitamin concentration of various fruits and vegetables. Under such conditions of fruit development, large variations in vitamin C concentration would be expected to occur in guava fruits."

The data in Table II emphasize the marked differences in the vitamin C content of varieties, as previously reported by the writer (8, p. 231). It will be noted, however, that the ascorbic acid determinations as given in this table are in general lower than those reported by Golberg and Levy (3 and 4), Boyes and de Villiers (2), or by Waddington and Cist (7). Although not entirely comparable, they are also lower than those shown by the analyses of the juice of some of the fruits of the same varieties in 1941 by Dr. Turrell (see Tables I and II for comparisons of the same varieties). Whether these differences are due to the methods of analysis, to environmental or seasonal variations, or to some other cause cannot be determined until further work is possible. Wokes, Organ, Duncan, and Jacoby (9) have recently directed attention to possible errors in vitamin C estimates, due

[3]The writer is under great obligation to his colleagues, Drs. Sinclair and Bartholomew, for their very kind cooperation.

to the presence of substances which they designate as "apparent vitamin C." It may be well to emphasize that their determinations were made with the dye 2:6-dichlorophenolindophenol, which is generally considered to be specific for vitamin C. The analyses reported in Table II were all made by the iodine titration method and are likely, therefore, to be truly comparable one with the other, if not with analyses made in other places.

Among the 19 varieties here reported, the highest ascorbic acid content for the skin and outer flesh of mature fruits was shown by the Rolfs with an average of 319 mgs of ascorbic acid to 100 grams of the fresh pulp. For contrast this may be compared with the low average of 49 mgs shown by the Lucene. The Rolfs variety also gave the highest ascorbic acid content in Turrell's analysis (Table I). The Hart, Riverside, and Volusia are also fairly high in these tests and also in those made by Turrell, while the Longped, a closely related variety, is in both cases rather low.

Similar differences between types of guavas are also indicated by the analyses reported by Golberg and Levy (3 and 4); Boyes and de Villiers (2) and Waddington and Cist (7); it is not clear, however, in all cases, that these investigators used fruit samples from single trees, or of known clonal varieties.

It is significant to note further that the first eight varieties given in Table II are all seedlings grown from the seed of a single fruit (open pollinated) of a Florida variety, the Detwiler; and yet these seedlings exhibit a range of vitamin C content from low (Longped, 90 to 99 mgs), to high (Rolfs 285 to 352 mgs). The evidence available seems to clearly indicate that clonal varieties differ greatly in their content of vitamin C, and that the commercial production of fruit of superior content can be obtained only as a result of the vegetative propagation of selected clones or varieties. It should of course be recognized that such high vitamin varieties must also be superior fruits in other important characters if they are to be valuable for commercial cultures.

Relation of Fruit Characters to Vitamin C Concentration

Flesh Color

Golberg and Levy (3 and 4) found the white-fleshed guava fruits to contain more vitamin C than red-fleshed fruits. In the analyses of the fruits at this Station, however, the Rolfs, a red-fleshed variety, in all tests thus far made, has given the highest vitamin C concentration (Tables I and II), but other red-fleshed varieties, such as the Webber and Lucene, were consistently low. Some white-fleshed varieties, such as Riverside and Hart, are uniformly high in vitamin C; but some others with white flesh, such as the Herradura, run low (Table II).

Boyes and de Villiers (2) stated that "types with salmon-colored flesh generally have a much lower vitamin C content than somewhat similar pink fleshed types." It seems probable that the types of Boyes and de Villiers with salmon-colored flesh are comparable in color with varieties the writer has designated as yellow-fleshed (by Ridgway's standards including maize yellow, apricot yellow, colonial buff, light

cadmium, etc.). The analyses of four such yellow-fleshed varieties in our collection (Table II) gave the following quantities of vitamin C: Longped, 90.1 and 98.8 mgs; Florence, 159.6 mgs; Arrons, 161.4 mgs; Diaz, 174 and 219 mgs. Comparing these quantities with other varieties in Table II, it will be seen that Longped ranks low, Diaz fairly high, with the other two varieties in intermediate position.

From the data now available it does not seem probable that flesh color is in any material degree correlated with vitamin C content. Waddington and Cist (7) also reported that no correlation could be found between color of fruit and vitamin C content.

Fruit Acidity

It is also interesting to note that degree of acidity, as judged by taste, apparently has little or no influence on the vitamin C content. Among the sweet varieties, Webber, Lucene, and Longped may be cited as running particularly low in ascorbic acid, approximately 50 to 90 mgs per 100 grams, while the sweet varieties Rolfs, Hart, and Riverside are among the highest, 160 to 400 mgs. Among the acid or very sour varieties, Wilder runs high, 200 to 300 mgs, while the Herradura, another very sour variety, analyzed only approximately 60 to 80 mgs of ascorbic acid.

The active acidity, pH, of the various varieties cultivated at this Station, has not been determined in all cases, but it is likely that all varieties may be considered as acid fruits. The juice of the six varieties listed in Table I, all classed as sweet guavas, gave pH readings between 3.62 and 3.85. It is probable that the very sour varieties, Wilder and Herradura, would show greater acidity, as they are much more sour to the taste. Taste, however, is a factor that is directly influenced by the sugar content, and judgment by taste may be deceptive.

Season of Variety Ripening

The season of ripening of a variety does not seem to have any marked influence on its vitamin C content, so far as indicated by the analyses of varieties grown at this Station (see Tables I and II). The earliest variety, the Ehrhorn, in the latter part of its season (for light-yellow firm fruits) yielded 154 mgs of ascorbic acid per 100 grams and the next earliest variety, the Rolfs, in the same stage of maturity gave the highest records of any variety in these tests, 284.9 and 352.4 mgs. The late ripening varieties, Florence and Arrons, gave respectively 159.6 and 161.4 mgs, and the latest variety, Wilder, 243.9. These results are too scanty to justify a definite conclusion but they suggest that the time of ripening of the various varieties is not strongly correlated with the vitamin C content of the fruit.

Period of Picking

Boyes and de Villiers (2) found that there was clearly an increase in vitamin C content of fruits as the season advanced, regardless of the fruit type, or apparently whether the fruit is of an early- or a late-ripening variety. Their type E, as an illustration, in July gave a vita-

min C concentration of 562 mgs, and in September this had advanced to 671 mgs. They also found that the vitamin C content of the canned product in Cape Provence, South Africa, increased sharply throughout the season from the last of April to the first of November. This increase is very strikingly shown by their data, as the average for the four dates in April was only 447 mgs of total ascorbic acid per can, while the average for the five dates in the last half of October was 2272 mgs per can. (2, p. 325, Table IV a.) As the vitamin C content of canned guavas was found to be very stable, the authors attributed this increase as probably due to the maturing of richer and richer types as the season progressed. Had early varieties rich in vitamin C content formed a considerable proportion of the early crop canned, the increase found doubtless would have been much less marked.

Judging from the meager data available it seems probable that within any clonal variety, whether early or late in season, its early-ripening fruits will contain a less concentration of vitamin C than its late-ripening fruits. In Table II the vitamin C content of mature fruits of five different varieties, Hannah, Marble, Herradura, Diaz and Giza, were reported for two different periods and although the interval between the analyses was short (16 to 34 days), there was a considerable increase in vitamin C at the later date in all varieties except the Marble.

Stage of Fruit Maturity

As guava fruits on the same bush continue to develop and ripen over a period of several months, it is of great importance in handling and utilizing the crop to know at what stage of maturity the fruits develop the highest concentration of vitamin C. Golberg and Levy (4, p. 8) found that green and hard fruits showed a fairly high concentration, ripe and firm fruits the highest concentration, and overripe soft fruits a considerable reduction. Boyes and de Villiers (2) gave special attention to this point and Table III gives their findings for three types apparently propagated mainly as clonal varieties.

These authors in discussing their studies stated: "The results . . . . definitely confirm our previous findings that there is no material loss of vitamin C when the fruit is picked ripe. In the Retief type there is only a slight loss when the fruit is left to become totally overripe. But as guavas are never allowed to get to this stage in practice the slight loss is of no consequence."

TABLE III—Effect of Stages of Fruit Maturity on Vitamin C Content*

	Milligrams Vitamin C to 100 Gms Fruit		
	Russouw Type	Malherbe Type	Retief Type
Green and hard	—	720	622
Yellowish green (softening)	—	684	614
Greenish yellow (canning ripe)	484	751	542
Yellow and fully ripe	522	761	583
Overripe	522	673	557
Badly overripe and unsaleable	—	697	476

*Quoted from Boyes and de Villiers, 1942, p. 328.

The analyses of different varieties at this Experiment Station made by Sinclair and Bartholomew provide additional information on this subject. An examination of the data (Table II) shows that in the cases of 15 varieties, where both mature and nearly ripe green fruits were picked on the same day and analyzed, all gave higher vitamin C concentration for the mature fruit. In another variety, the Ehrhorn, the light-yellow firm fruits picked on November 16 were doubtless at the proper stage of maturity to use, and analyzed 154 mgs; while those picked December 9 and labeled "mature" were probably over-ripe and yielded only 96 mgs.

The preponderance of evidence available indicates that the vitamin C content of the fruit is likely to reach its highest concentration in the period between early ripening, at which time the fruits are still firm but are beginning to turn light yellow, and the time when they can be considered fully mature, that is, when they have obtained the full yellow color of maturity and are just beginning to mellow. The fruits for commercial handling should apparently be picked in the early stages of this period, but for immediate home use they are commonly more acceptable in the later fully mature stage.

Doubtless many environmental factors such as the quantity of heat, light, nutrition, water, fertilizer, rootstocks, soil type, and the like may affect the concentration of vitamin C in the fruit but such influences have not yet been studied with the guava.

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Climate in Relation to Deciduous Fruit Production in California. III. Effect of Temperature on Number of Days from Full Bloom to Harvest of Apricot and Prune Fruits

By GEORGE A. BAKER and REID M. BROOKS, *University of California, Davis, Calif.*

TO KNOW the approximate date of the beginning of harvest well in advance would help the grower considerably in making his plans —for example, in securing labor at the right time, getting his equipment in shape, and giving the last irrigation and cultivation before picking starts. These facts are particularly pertinent just now, when labor is scarce and equipment difficult to obtain. An attempt has been made to determine as early as possible in the growing season the probable time when fruit harvest will begin. Since the results to date are encouraging, they are published here in a preliminary way. They are based on 17 years' records for apricots in the Winters district and on 13 years' records for prunes at Davis. Though predictions of harvest in other fruit areas in California should be studied also, the present paper does show that this type of experimental research has promise.

The interval that elapses between full bloom and fruit maturity, aside from temperature during the whole or part period and aside from probability considerations, has been used as an index of fruit harvest and of predicting the time of such harvest. According to data presented by Magness *et al* (15), Magness, Diehl, and Haller (14), Ryall, Smith, and Pentzer (17), Haller (10), and Tukey (20), the number of days between full bloom and harvest of fruits is consistent year in and year out for many varieties of apples, pears, peaches, and cherries; behavior is similar from year to year. For apples, however, Ellenwood (7) found that "there was a great variation between the fewest and the greatest number of days intervening between bloom and harvest." For ten commercial apple varieties over a 30-year period Ellenwood showed that there was a maximum of 36 days and a minimum of 14 days, with an average of 23.4 days' difference between bloom and harvest; in his opinion "an accumulated record of bloom and picking dates should be helpful in establishing proper picking dates but cannot be used as a fixed rule." For French prunes and Royal apricots in California, the data resemble those presented by Ellenwood for apples: the number of days between full bloom and harvest has a range of 19 days in 17 years for apricots, and 20 days in 13 years for prunes. In an attempt to predict the time of first picking more accurately for these fruits, studies were initiated using as a basis the heat accumulated during the growing season. The factors of rainfall and sunshine may be minimized in the present account: the hours of possible sunshine were nearly constant over the periods under investigation; and where rainfall did not supply enough soil moisture, the orchards were irrigated.

During the years for which the records were used, the same individuals observed and recorded the dates of full bloom and of harvest—all in the same orchards. The Royal apricot data were secured at Winters from a commercial orchard where the fruit was grown for early shipment to eastern markets; therefore, "harvest" of apricots refers to "first shipping" maturity only. The French prune data were obtained at Davis from a large experimental orchard that was used for irrigation trial plots; here, "harvest" refers to "full ripe" maturity only. In no part of the orchard, during any year since the records began, did different irrigation treatments cause any observable difference in time of full bloom; maturity of fruit was consistent through the years on both the wet and the dry plots.

Methods and Data

Various amounts of heat (6) and various fruit districts having the same amount of heat (19) are known to affect the time of maturity for even the same variety of fruit. It remains, therefore, to find a basis whereby these effects of heat may be measured and utilized in determining the length of the period between full bloom and the harvest date. Of the many methods that have been used in measuring heat during the growing season (1, 4, 5, 13, 18, 19, 21), cumulated seasonal heat units were chosen as expressing more accurately the effect of heat on fruits. For purposes of this investigation a heat unit has been arbitrarily defined as 1 degree F per day above a given base temperature, 45 degrees. Heat units were obtained from continuous temperature data recorded by a thermograph near each of the orchards. To compute the number of heat units, a planimeter determination of the area above the base line was made and the resulting figures were multiplied by a factor to change them to heat units per week. Lilleland (13) has discussed this method in some detail in his work on the growth of apricot fruits in relation to temperature.

The dates of full bloom and of the beginning of harvest were noted for as many years as temperature records were available. Admittedly, the exact dates for these two growth phases in the life of the tree are sometimes uncertain from the viewpoint of the observer. The proper time to start picking is undoubtedly much more definite for apricots than it is for prunes. These slight uncertainties make for a less faithful prediction than would otherwise be possible.

In predicting the number of days from full bloom to harvest, three progressively complex statistical techniques have been employed. First, the simplest is to consider the mean number of days and the probability that the number of days next year will fall within a certain interval centered at this mean. This is merely a more precise application of Tukey's method (20), which did not allow adequately for the number of years nor for the probability of different-sized deviations. Second, the correlation of cumulated heat units with the number of days served as a basis for improving our estimate of the date of harvest. Third, we have applied a method developed by R. A. Fisher (8) for estimating the relation between heat units and number of days from full bloom to harvest throughout the season. This relation is

then used to make a succession of estimates as the season progresses and as the information on heat units becomes available.

Estimate 1. Prediction Based on the Mean:—After making a number, say n, of observations on the number of days from full bloom to harvest for a particular fruit, one can venture to predict what this number of days will be in the future. The procedure has been discussed by Baker (3) in general terms. In the present study we need only observe that the quantity

$$\text{(A)} \qquad t = \frac{\sqrt{n}}{\sqrt{n+1}} \left(\frac{\bar{x} - z}{s}\right)$$

is distributed as t with $n - 1$ degrees of freedom where n is the number of years for which observations have been made, $\bar{x}$ is the mean for the observed years, s is the root residual mean square (that is, the square root of the sum of squares of the residuals divided by the number of degrees of freedom), and z is the unknown or predicted value for the next year. Thus from the usual t-tables, available in various places, for instance those of Gosset (9), we can compute the probability that the next year's number of days from full bloom to harvest will have or exceed a given value. The data gathered each year are incorporated into formula A, above, for making the prediction for the next year. Thus n increases as the years go by, and so does the accuracy of our estimate, since the number of degrees of freedom on which s is based becomes greater. Also as n increases, the factor $\sqrt{n}/\sqrt{n+1}$ approaches 1, and formula A becomes the usual t as defined by "Student" (9).

Table I gives the data on days from full bloom to harvest and on heat units by weeks for 17 years for Royal apricots at Winters, California. In this case, considering only number of days, formula A becomes

$$(A_a) \qquad t = \frac{\sqrt{17}}{\sqrt{18}} \left(\frac{82 - z}{4.66}\right) = \frac{82 - z}{4.80}$$

with 16 degrees of freedom. Let us compute z, arriving at the probability of 0.50 that next year the number of days from full bloom to harvest lies in the interval $82 \pm z$. Since t for 16 d. f. and for $P = 0.50$ is 0.690, we find that z equals 3.3; or, roughly, the probability is 0.50 that next year the time between full bloom and harvest for Royal apricots at Winters will be 79 to 85 days.

In Table II appear the data on number of days from full bloom to harvest and on heat units each week for French prunes at Davis. The figures are less satisfactory than for apricots because there are fewer years, the date of harvest is less definite, and the period between full bloom and harvest is much longer.

Corresponding to formula A_a we have

$$(A_p) \qquad t = \frac{\sqrt{13}}{\sqrt{14}} \left(\frac{158 - z}{5.56}\right) = \frac{158 - z}{5.77}$$

TABLE I—DATES OF FULL BLOOM AND FIRST PICKING, OBSERVED AND ESTIMATED NUMBER OF DAYS BETWEEN THESE DATES, AND HEAT UNITS (45 DEGREES F BASE LINE) BY WEEKS DURING THE SAME PERIOD, FOR ROYAL APRICOTS FOR 17 SEASONS AT WINTERS, CALIFORNIA

Year	Date of Full Bloom	Date of First Picking	Number of Days from Full Bloom to First Picking*			Heat Units for Whole Weeks between Full Bloom and First Picking												
			Obs	Est 2	Est 3	1	2	3	4	5	6	7	8	9	10	11	12	13
1927	Mar 14	June 2	80	85	85	41	74	55	53	78	136	126	123	192	127	143	167	—
1928	Mar 3	May 25	84	83	84	72	83	90	59	82	102	88	127	157	131	152	199	—
1930	Mar 3	May 26	84	80	83	53	50	95	165	113	110	119	124	100	105	136	173	—
1931	Feb 23	May 13	79	79	76	76	97	83	131	97	135	148	182	137	141	232	—	—
1932	Feb 27	May 23	86	80	83	86	84	104	104	118	108	112	120	92	102	144	209	145
1933	Mar 9	June 3	86	79	83	93	78	62	117	122	151	126	109	82	104	107	208	160
1934	Mar 1	May 14	74	76	72	99	112	126	111	117	143	160	182	149	166	212	—	—
1935	Mar 4	June 3	91	88	88	21	55	26	86	79	78	109	148	147	134	162	182	195
1936	Feb 25	May 14	79	81	82	70	99	124	109	53	41	149	137	145	119	185	182	—
1937	Mar 7	May 29	83	84	82	83	49	48	94	78	121	127	117	145	227	177	192	—
1938	Mar 5	May 30	86	85	83	39	51	79	71	95	116	155	93	153	195	169	188	—
1939	Mar 7	May 18	72	78	77	39	107	90	103	187	142	168	142	156	176	110	—	—
1940	Mar 2	May 22	81	82	81	79	63	117	64	73	143	147	72	120	186	211	—	—
1941	Mar 4	May 24	81	83	83	66	97	96	94	63	93	104	149	118	180	130	192	—
1942	Mar 8	June 2	86	84	86	52	81	74	88	103	61	125	77	121	105	196	135	—
1943	Mar 1	May 23	83	84	84	58	71	43	99	98	99	127	109	126	182	138	236	—
1944	Mar 10	May 29	80	81	81	83	69	98	124	92	86	98	116	224	131	149	218	—

*Estimate 1 is the mean number of days, 82, and, being the same for each year, is not tabulated.
Estimate 2 is based on accumulated heat units for the first 6 weeks.
Estimate 3 is based on R. A Fisher's method of determining the average effect of heat units for each of 11 weeks on the number of days from full bloom to first picking.

with 12 degrees of freedom. For instance, the probability is 0.50 of a next year's number falling between 154 and 162. In 1944 the observed number of days was 148; hence t equals 1.73 and $P > 0.05$.

Estimate 2. Correlation of Number of Days with Heat Units:—As formula A indicates, if we could reduce s, the sharpness or precision of our estimate would thereby be increased. Also if we could center our interval on a point, represented by $\bar{x}$, that was better for the particular kind of year for which we are trying to predict harvest date, our estimate would be improved. As is well known, the supply of heat affects the speed of the bio-chemical reactions on which the growth and ripening of fruits depend (11). A hopeful method of trying to reduce s and improve our estimate of $\bar{x}$, therefore, is to consider the relation of heat units (degree-days above 45 degrees F) for partial or whole periods to the number of days from full bloom to harvest, which is a measure of the speed of all the reactions necessary to produce the ripened fruit.

For instance, we might observe the heat units for a partial period and use this information to reduce s and estimate $\bar{x}$. As s is reduced by statistical means, degrees of freedom are lost—a loss that adversely affects the precision of formula A. Thus the statistical reduction of s may soon reach a point of lessened precision unless many years' data are available. In order to determine the best partial period to use in these computations, a series of correlations were determined for the accumulation of heat units for various weeks in relation to actual

TABLE II—DATES OF FULL BLOOM AND HARVEST, OBSERVED AND ESTIMATED NUMBER OF DAYS BETWEEN THESE DATES, AND HEAT UNITS (45 DEGREES F BASE LINE) BY WEEKS DURING THE SAME PERIOD FOR FRENCH PRUNES FOR 14 SEASONS AT DAVIS, CALIFORNIA

Year	Date of Full Bloom	Date of Harvest	Number of Days from Full Bloom to Harvest*			Heat Units for Whole Weeks between Full Bloom and Harvest Date																							
			Obs	Est 2	Est 3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1931	Mar 21	Aug 21	153	155	154	62	109	109	128	116	128	172	143	166	177	139	154	135	199	280	232	197	245	176	172	197	196	—	—
1932	Mar 16	Aug 25	162	162	162	72	79	87	85	91	62	77	107	150	106	149	114	167	143	205	235	203	159	185	193	212	162	173	—
1933	Apr 5	Sep 11	160	159	163	73	105	80	69	54	69	76	176	127	161	170	176	160	176	236	230	240	163	241	233	166	146	142	—
1934	Mar 13	Aug 24	165	159	157	100	79	84	95	110	128	98	106	169	139	133	133	161	159	166	204	164	193	168	208	192	206	216	174
1935	Apr 3	Sep 11	162	158	159	57	67	83	108	96	85	113	135	146	178	156	203	169	133	207	189	179	177	207	161	195	177	147	—
1936	Mar 16	Aug 26	164	161	164	87	41	31	121	94	108	88	143	151	164	96	104	175	188	204	185	172	225	227	205	244	218	143	—
1937	Apr 4	Sep 9	159	155	154	65	99	112	92	106	173	139	155	167	135	162	221	233	223	160	230	182	196	217	196	175	139	—	—
1938	Mar 31	Sep 5	158	158	159	52	68	85	93	65	105	142	138	154	214	133	188	177	135	166	202	230	210	204	176	159	149	178	—
1939	Mar 25	Sep 1	161	156	154	80	153	91	117	104	101	140	86	165	166	191	134	218	165	184	203	215	184	184	175	210	165	153	—
1940	Mar 24	Aug 16	145	156	148	66	63	130	122	62	97	155	189	150	118	211	216	175	192	228	164	150	187	185	204	166	—	—	—
1941	Mar 21	Aug 20	153	159	160	79	46	63	78	105	95	148	113	159	115	173	194	144	149	218	196	203	165	165	181	199	—	—	—
1942	Mar 23	Aug 31	162	160	163	68	75	88	70	110	65	108	94	171	124	154	182	181	196	245	206	191	238	182	204	208	211	156	—
1943	Mar 19	Aug 18	152	156	157	89	85	86	106	109	111	154	123	210	164	148	135	198	155	189	227	187	211	247	194	194	—	—	—
1944	Mar 28	Aug 23	148	158	158	104	79	68	73	90	169	107	116	167	122	195	112	140	211	187	201	197	186	199	214	179	211	—	—

*Estimate 1 is the mean number of days, 158, for the first 13 seasons and, being the same for each year, is not tabulated.
Estimate 2 is based on accumulated heat units for the first 12 weeks for the first 13 seasons
Estimate 3 is based on R. A. Fisher's method of determining the average effect of heat units for each of 21 weeks on the number of days from full bloom to harvest for the first 13 seasons.

harvest time. It was found that the first six weeks' period for apricots and the first twelve weeks' period for prunes gave nearly as high correlation as any period one may take. In each case, this period corresponds to the first half of the growing season. From the viewpoint of the pomologist, knowledge of the approximate harvest date at the half-way mark would be of great help.

If we consider the total heat units for the first six weeks after full bloom, formula A_a by analogy becomes for apricots

$$(A_a') \qquad t = \frac{\sqrt{16}}{\sqrt{17}} \left(\frac{82 - 3.19(h - 5.31) - z}{3.68} \right)$$

with 15 degrees of freedom, where *h* is hundreds of heat units in the first six weeks. For instance, if next year we find 8.00 hundred heat units the first six weeks, the probability is 0.50 that the time between full bloom and harvest will be 71 to 76 days.

When we try to improve our estimate for prunes on the basis of heat units, we are on somewhat shaky ground: the data indicate a statistical significance of only about 1 in 10, which is not very high. If, however, we are willing to assume that there is a relation between the number of days and the number of heat units to the end of 12 weeks, then corresponding to formula A_a' we have

$$(A_p') \qquad t = \frac{\sqrt{12}}{\sqrt{13}} \left(\frac{158 - 1.57(h - 14.23) - z}{5.42} \right)$$

with 11 degrees of freedom. In 1944 we had 14.02 hundred heat units in the first 12 weeks. We therefore expect, with a probability of 0.50 of being right, that the number of days this year will lie between 154 and 162. If, however, next year the heat units went up to 18.00 hundreds, then we expect the number of days to be between 150 and 158.

Estimate 3. R. A. Fisher's Method, Relation of Heat Units to Number of Days throughout the Season:—R. A. Fisher (8) has devised the method that secures the greatest reduction of *s* and that best predicts the number of days from full bloom to harvest, based on heat units observed during a current season. His procedure is well explained by Houseman (12) and by Anderson and Houseman (2). The method is based on computing the average effect of, say, 100 heat units on the days from full bloom to harvest for every week during the season. Presumably, this effect can be represented by a polynomial. Fig. 1 shows the effects for apricots and prunes, assuming that the average effect can be represented by a straight line. The data are not adequate to permit a more elaborate determination.

If we use Fisher's method to determine how heat units affect the number of days from full bloom to harvest for apricots, using the first 11 weeks of Table I, and assume that the relation is linear, we obtain the result given in Fig. 1. This shows that excess heat units shorten the number of days and that this shortening is somewhat more marked early in the season. That the effect is highly significant statistically is clear from Table III. The q_1 of Houseman's (12) notation, which

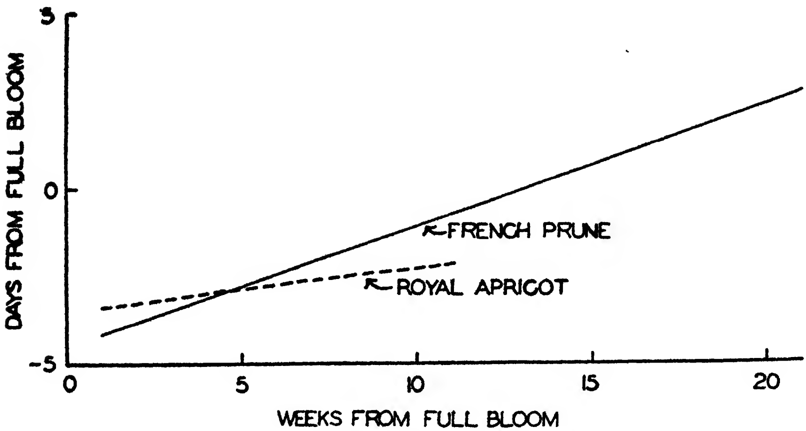

FIG. 1. Average effect of 100 heat units on the number of days from full bloom to harvest for Royal apricots at Winters (17 years' data) and for French prunes at Davis (13 years' data).

gives the slope to the line of Fig. 1, is not, however, statistically significant by itself. Even though a real effect of this kind may be present, it is too small to be demonstrated by the data available thus far. The correlation between number of days and total heat units for the first 11 weeks is − 0.82, a figure that accounts for nearly all of the relation between the two variables. These values may be contrasted with those for prunes, which will be presented later. For apricots $\alpha_0 = -2.809$, and $\alpha_1 = 0.1154$.

On the basis of the line for apricots in Fig. 1, estimate can be made of the number of days from full bloom to harvest as indicated by Houseman. We multiply the ordinates of this line by the corresponding excess or deficit of 100 heat units per week as compared with the average number of heat units. These are added algebraically to the

TABLE III—ANALYSIS OF VARIANCE FOR EFFECT OF HEAT UNITS ON NUMBER OF DAYS FROM FULL BLOOM TO HARVEST FOR ROYAL APRICOTS, WINTERS, CALIFORNIA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	16	347.00	——
Residuals	14	108.24	7.73
Regression	2	238.76	119.38

$$F = 15.44 \text{ with 2 and 14 d. f. } P<0.01$$

mean number of days from full bloom to harvest, to determine the desired estimate. For instance, to estimate Y, the number of days from full bloom to harvest, at the end of the first six weeks for 1935 we have

$$\text{(B)} \quad Y = 82 + (0.21 - 0.65)(-3.39) + (0.55 - 0.78)(-3.27) + (0.26 - 0.83)(-3.15) + (0.86 - 0.98)(-3.04) + (0.79 - 0.97)(-2.92) + (0.78 - 1.10)(-2.81) = 88.$$

The observed number of days was 91.

If we treat the prune data according to Fisher's method we get Table IV, corresponding to Table III.

TABLE IV—ANALYSIS OF VARIANCE FOR EFFECT OF HEAT UNITS ON NUMBER OF DAYS FROM FULL BLOOM TO HARVEST FOR FRENCH PRUNES, DAVIS, CALIFORNIA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	12	401.72	——
Residuals	10	233.31	23.33
Regression	2	168.41	84.20

F = 3.61 with 2 and 10 degrees of freedom
F = 4.10 for 5 per cent level of significance

In contrast with the apricots, $\alpha_0 = -0.7175$, $\alpha_1 = 0.3408$. Fig. 1 shows the relation of number of days to heat units for 21 weeks. The slope, greater than for apricots, indicates that high temperatures late in the season may inhibit the ripening of prunes. This finding is in conformity with the results of Overholser and Taylor (16) for pears. It is partially supported by Hendrickson and Veihmeyer (11) who report that high temperatures, especially above 105 degrees F, damage prunes, causing a decrease in the specific gravity of the dried fruit. This damage may also inhibit the ripening process.

SUMMARY

Various investigators have called attention to the consistency of the number of days to harvest when measured from full bloom. For some varieties and localities there is little variation in the number of days from full bloom to harvest. For Royal apricots at Winters and French prunes at Davis, California, however, the variation is too great to permit sufficiently accurate estimates for a next year on the basis of past years' experience. In an attempt to improve the accuracy of the estimates of the number of days from full bloom to harvest, accumulated seasonal heat units were considered. On this basis the estimates for apricots were greatly improved, whereas the estimates for prunes were not improved to so great an extent. As data are accumulated, more elaborate analysis will be possible that may permit estimates of still greater accuracy.

The statistical techniques used in making such estimates should give full consideration to the number of years for which data are available and to the probabilities of various size deviations. This is accomplished by successive modifications of "Student's" *t*-test. As an intermediary step in one method of estimation, the effect of an above-average number of heat units on the number of days from full bloom to harvest is found for each week during the season. For apricots, excess heat units decrease the number of days from full bloom to harvest; but the effect is less pronounced as the season progresses. Much the same is true for prunes; in addition, however, there is some indication that high temperatures late in the season may actually retard ripening.

By using the three statistical methods evolved for the prediction of harvest time, the apricot results indicate that for 3 out of 17 seasons the predicted date of harvest was the same as the actual harvest date; in 8 seasons the predicted date was within 1 day of actual harvest. In no year was the predicted harvest date more than 5 days from the observed day on which apricot picking was begun. In the case of prunes, for 3 out of 14 seasons the predicted date was the same as the actual harvest date; for 8 seasons the predicted date was within 3 days of harvest; in 5 years, the discrepancy was from 4 to 6 days, and in 1 year the prediction was off 10 days. Therefore, for the data now available, apricot harvest was predicted within 3 days of actual harvest time 80 per cent of the time and for prunes 50 per cent of the time, by using the statistical methods outlined in the paper. Observations have shown that some deviation occurs in a given district as a result of local climatic variations and cultural practices; the individual grower must relate the statistical methods given here to the conditions existing in his orchard.

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A Study of the Skin Structure of Golden Delicious Apples

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The structure of the skin of fruits of the apple has been studied by a number of investigators (1, 2, 3, 4, 6, and 7). It has been assumed by some persons that cracks through the cuticle into the epidermis are always healed or protected by normal periderm. If cracks or injuries penetrate into the hypodermis or cortex, disfiguring lesions are usually found. Baker (1) showed that russeted apples lose more weight in storage than apples having normal skins, but it hardly seems logical that the amount of russet on Golden Delicious apples could account for the severe shriveling which usually occurs during the storage of this variety. The object of this study was to determine the cause of the excessive shriveling of Golden Delicious apples.

Materials and Methods

The apples used were obtained in 1939 and 1940 from the orchard of the University of Tennessee College of Agriculture. The samples were collected and stored in formalin-alcohol-acetic preservative. Portions for study were imbedded in paraffin by the Zirkle (8) n-butyl alcohol method. Sectioning was done with a rotary microtome at a thickness of 10 microns. Staining was done with Delafield's haematoxylin and Sudan III, and the mounts were made with white Karo syrup (5).

Results and Observations

Collection of material in 1940 began on April 1, at which time the winter buds were in a very little more advanced stage than the "delayed-dormant" condition. With only a few exceptions, samples were taken every day until May 28. Thereafter they were taken at intervals of one week.

On April 1, the epidermal structure was prominent, the cells for the most part being uniform. A few of them, however, were elongated into hairs. On April 8, the blossoms were in the "pink-bud" stage. The epidermal cells were regular in shape, being about twice as long radially as they were wide tangentially. There was only slight indication of cuticular development on the surface of the young fruit.

The data in Table I show the progressive changes in stage of flower or size of fruit throughout the season, along with the thickness of cuticle and the radial and tangential measurements of the epidermal cells of Golden Delicious apples.

Cool weather delayed the development of the flowers and it was not until April 17 that they were in full bloom. On April 22, they had lost practically all of their petals. Fig. 1 is a drawing of the epidermal region of a Golden Delicious fruit at that time. The noticeable changes from previous stages were a slight increase in cuticle, particularly

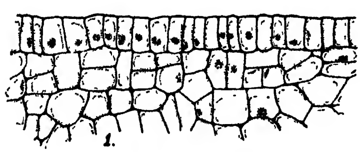
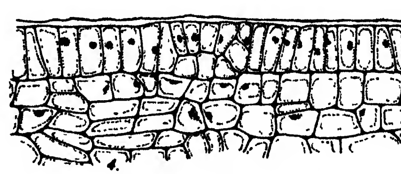
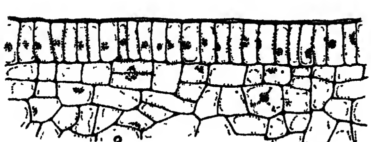
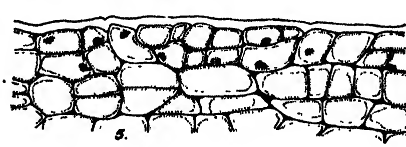
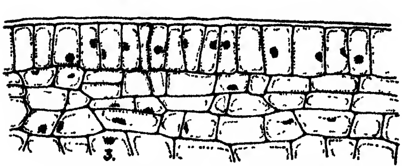
TABLE I—MEASUREMENTS OF CUTICLE AND EPIDERMAL CELL OF GOLDEN DELICIOUS APPLES DURING THE SEASON OF 1940

Date of Sample	Stage or Size of Fruit (Cms)	Thickness of Cuticle (Microns)	Epidermal Cells	
			Radial (Microns)	Tangential (Microns)
April 8	Pink Bud	—	16.20	7.85
April 22	Petal Fall	—	16.65	7.02
April 29	0.5	—	23.50	7.10
May 6	0.9	2.00	25.50	7.87
May 11	1.1	2.00	26.20	8.66
May 17	1.7	3.00	23.46*	12.10
May 24	2.3	5.50	21.70	14.65
June 5	3.0	7.10	21.80	18.15
July 3	5.1	8.58	15.66	21.50
July 25	6.1	9.33	14.33	24.17
Sept 20	7.5	13.18	11.62	28.25

*This figure was obtained by measuring epidermal cells which had not divided periclinally. In many cases the cells had divided, and the resulting daughter cells were about one-half this figure. In succeeding measurements in this column, the same procedure was followed.

around the hair bases, and radial division of the epidermal cells. Mitotic figures were extremely difficult to find, and the conclusion regarding radial division was reached primarily because the fruit had increased in size and the cells had increased slightly in the radial dimension and decreased in tangential measurement. A few cases of periclinal division of the epidermal cells were observed at this early stage of the fruit.

It is to be noted that in the early stages the cuticle was not distinct and measurable. The outer tangential walls of the epidermal cells took a small amount of the Sudan III stain, which indicated the deposition of waxy materials.

FIGS. 1–5. Cross sections of the skin of Golden Delicious apples. 1. At petal-fall. 2. When the small fruit was 0.5 cm in diameter. At this stage the cuticle was hardly as distinct as shown in the drawing. 3. When the fruit had reached 0.9 cm in diameter. At this stage the cuticle was very distinct. 4. When the fruit was 1.7 cm in diameter. At this stage periclinal division was prominent. 5. When the fruit was 2.3 cm in diameter.

On April 29, the fruits averaged 0.5 centimeter in diameter, and the thickness of the cuticle still could not be measured accurately. The epidermal cells became even longer radially with only a slight increase tangentially. The increase in size of fruit, accompanied by this change in the size of epidermal cells, indicates that these cells were being divided radially (Fig. 2).

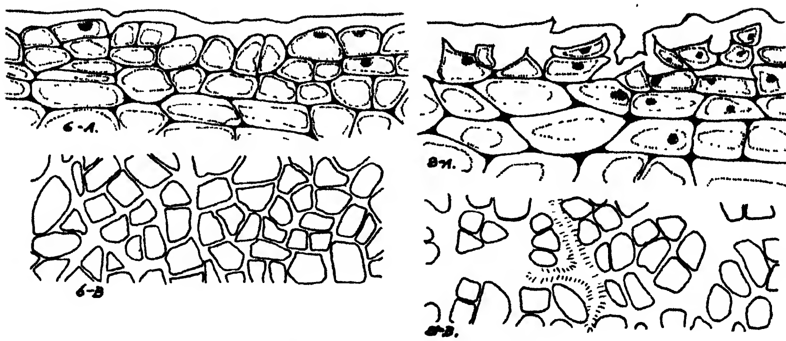
The fruits increased in size rapidly. By May 6, they averaged 0.9 centimeter in diameter, and the cuticle was distinct, uniformly 2 microns in thickness. The epidermal cells continued to elongate radially, but at a less rapid rate; and, with some increase in tangential width, it is probable that radial division of these cells was much less than formerly. Five days later, May 11, the changes which had occurred showed the same gradual trend (Fig. 3).

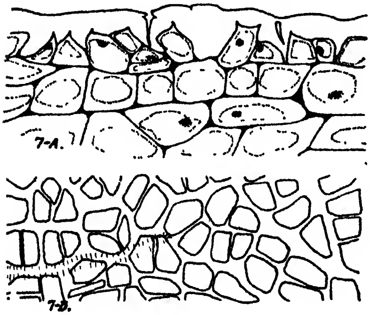
Materials collected on May 17 showed marked changes. A few cells had divided periclinally as early as the full bloom stage, but on the above date division in this direction was conspicuous, as is shown in Fig. 4. This, in reality, was a point of transition in the development of the skin of the Golden Delicious apples. The fruit measured 1.7 centimeters in diameter, and the cuticle was uniformly 3 microns in thickness. Some of the epidermal cells were dividing as just indicated, and those that were not dividing were becoming shorter radially. Along with these changes, there was an increase in the tangential measurement of more than 39 per cent in 6 days' time (Fig. 4).

During the remainder of the season, the fruits increased regularly in diameter. The cuticle thickened gradually, and the epidermal cells continued to become shorter in radial measurement, while at the same time they were stretched tangentially. Accompanying the changes indicated in Table I, there were changes which cannot be expressed in tabular form. These were irregularities of the epidermis as a result of periclinal division and the breaking of the cuticle. They are illustrated in Figs. 5, 6, 7, and 8. On July 3, numerous cracks were observed in the cuticle. As shown in Figs. 7 and 8, both in cross section and in surface view, the cracks occurred mostly between groups of epidermal cells.

As the fruits increased in diameter, the cracks became wider and more numerous. The walls of many of the epidermal cells in some way were drawn into "tubes", and in many of these cases the "tubes" extended to the surface of the cuticle. In addition, the cracks generally extended to the epidermis or hypodermis. Frequently, air spaces were seen within the cuticle, and many epidermal cells were completely surrounded by cuticle. Such conditions are illustrated in Fig. 9. Only occasionally was the cuticle found to be fairly continuous and smooth, as is shown in Fig. 10. Even there the "tubes" of some of the epidermal cells traversed the cuticle to the surface.

A parallel study was made of Winesap apples. Results are shown in Table II. The changes were much the same as in Golden Delicious, the principal difference being that the cuticle of Winesap did not become as thick as that of Golden Delicious; and the greatest radial measurement of epidermal cells was reached on May 6 in the Winesap





FIGS. 6–8. Cross sections (A) and surface views (B) of Golden Delicious apples. 6. When the fruits were 3.0 cm in diameter. 7. When the fruits were 5.1 cm in diameter. Cracks had formed in the cuticle, primarily between the groups of cells. 8. When the fruits were 6.1 cm in diameter.

and on May 11 in Golden Delicious. Size of fruit and tangential dimensions of epidermal cells did not differ much.

A great difference was observed in the structure of the two varieties. In contrast with the Golden Delicious, the Winesap exhibited a fairly even surface of the cuticle. Both varieties showed marked periclinal division of the epidermis. In Winesap, as the fruit enlarged, the cuticle stretched and some of it was deposited between the epidermal

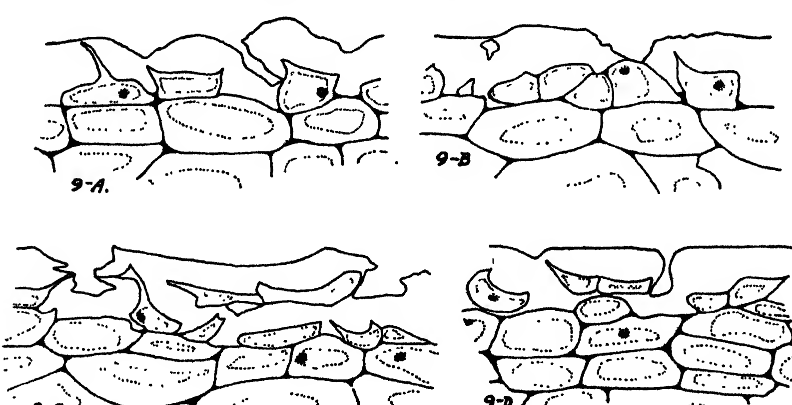


FIG. 9. Typical breaks, cracks, "tubes", and exposed cells found in mature Golden Delicious apples, shown in cross section.

TABLE II—MEASUREMENTS OF CUTICLE AND EPIDERMAL CELLS OF WINESAP APPLES DURING THE SEASON OF 1940

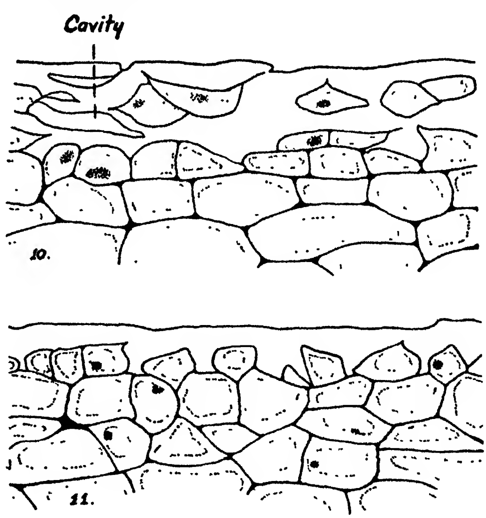
Date of Sample	Stage or Size of Fruit (Cms)	Thickness of Cuticle (Microns)	Epidermal Cells	
			Radial (Microns)	Tangential (Microns)
April 1	Cluster Bud	—	13.10	6.51
April 8	Pink Bud	—	15.50	7.18
April 22	Petal Fall	—	14.80	7.32
April 29	0.45	2.00	20.90	8.33
May 6	0.80	3.00	24.40	9.30
May 11	1.20	3.00	20.10	9.67
May 17	1 85	3.00	19.58	12.50
May 24	2.55	5.00	16.25	14.58
June 5	3.20	7.70	15.25	15.98
July 3	4.55	11.58	15.66	16.66
July 17	5 00	10.66	15.27	19.00
Sept 20	6.10	10.00	15.13	23.95
Oct 3	7.05	10.58	14.50	26.33

cells. Also, the cuticle of Winesap appeared to be more oily than that of Golden Delicious. Fig. 11 illustrates the Winesap tissue in cross section.

DISCUSSION

There is no question as to the prevalence of cracking in the cuticle of Golden Delicious apples. Fruits were observed from three widely separated sections of the country, the Pacific Northwest, Kansas, and Tennessee, and cracking was a common characteristic. The fruits from the Pacific Northwest had the least russet.

The skin of Golden Delicious develops much the same as that of other varieties until about the middle of May, when the fruits are about ⅝ inch in diameter. The epidermis then undergoes considerable periclinal division, and from that time on is very irregular. Accompanying this irregularity, as would be expected, is an unevenness of the cuticle. About the first of July, when the



FIGS. 10–11. 10. An example of fairly smooth and continuous cuticle of Golden Delicious apples. This is not the usual condition. Even here there were cavities in the cuticle. 11. Cross section of skin of a mature Winesap apple. In contrast with the Golden Delicious illustrated in Figs. 9 and 10, the cuticle of the Winesap has a smooth surface, and it is unbroken. The epidermal cells are not stretched, but instead they have become separated and cuticle has deposited between them.

fruits are approximately 2 inches in diameter, cracks make their appearance in the cuticle. Subsequent enlargement of the fruits causes the cracks to extend and widen. The mature apples, some of which measure 3 or more inches in diameter, generally have a badly cracked cuticle, with many of the epidermal cells and some of the hypodermal cells unprotected by either cuticle or cork.

The skin of the Winesap goes through a similar type of development, except that the cuticle rarely cracks. The Winesap, however, seldom reaches the large size of the Golden Delicious, and probably therefore the cuticle is not subjected to so great a strain.

These observations on the Golden Delicious are in agreement with those of Tukey and Young (6) on the McIntosh. No intensive study was made of the russeted areas on the Golden Delicious, but those patches that were observed seemed to be normal lenticels, as reported by Clements (4) and normal periderm as reported by Bell (2). Nothing was observed that resembled the Bordeaux-induced russet studied by Bell (3). The cracks formed in this variety are not deep and disfiguring as in the Stayman (7).

This study shows that many of the cracks in the cuticle of the Golden Delicious reach the epidermis and the hypodermis, yet remain unprotected by cork or other tissue. It is believed that these unhealed cracks in the cuticle account for the excessive shriveling of Golden Delicious apples during the storage period.

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Thiocyanate Induced Chlorosis Predisposes Development of Anthocyanin by Exposing Apple Skin Tissue to More Blue-Violet Light

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ABSTRACT

This is an abstract of a thesis presented to the State College of Washington in partial fulfillment of the requirements for the degree of Doctor of Philosophy. A more complete discussion is being prepared for publication in the *Journal of Agricultural Research.*

DEVELOPMENT of red color is an important limiting factor in the production of high grades of red varieties of apples. This color results from the development of anthocyanin pigment chiefly in the outermost hypodermal cells of the apple skin, although a slight amount of pigmentation persists in the epidermal tissue.

Chlorosis of apple fruits was obtained by etiolation in black paper bags. When these fruits were exposed to moderate sunlight, they rapidly developed anthocyanin on their surfaces far surpassing development on non-etiolated fruits. This color later showed a tendency to fade, possibly because etiolated fruits have no clearly differentiated hypodermal tissue. Anthocyanin was confined to the epidermal tissue, where it was more ephemeral.

The development of anthocyanin in apple fruits is not only affected by natural environmental factors but may be induced by thiocyanate sprays. Dustman and Duncan (1) found that anthocyanin development was increased in apples receiving sprays of soluble thiocyanates. Further trials (2) during the following season confirmed these results and indicated that the thiocyanate ion was the effective agent irrespective of the positive ion with which it was associated.

Thiocyanate-induced chlorosis may be corrected by applying soluble iron sprays or injections. This indicates that the physiological effect of the thiocyanate ion lies in its ability to combine with iron, which is essential for the formation of chlorophyll in the apple skin tissues.

Histological studies showed an inverse relationship between the presence of chlorophyll and anthocyanin in epidermal and hypodermal cells. Chlorosis of these tissues, induced by thiocyanate sprays, which did not impair their vitality was followed by increased anthocyanin development, particularly in the hypodermal tissue. Fruit chlorosis resulting from thiocyanate sprays exposed the hypodermal cells to more blue-violet light and was followed by increased anthocyanin development. This development occurred most rapidly from August 15 to September 15. Before this period anthocyanin development took place slowly, and afterwards it soon entirely ceased because of the loss of vitality by the epidermal and hypodermal cells.

Quantitative determinations of the milligrams of chlorophyll per square meter of fruit skin surface showed a much lower chlorophyll content for the sprayed than the unsprayed fruits.

Thiocyanate sprays, unfortunately, resulted in foliage chlorosis as well as fruit chlorosis. Mature foliage was more resistant after terminal buds had formed. The thiocyanate ion may not have destroyed chlorophyll but merely inhibited the formation of chlorophyll to replace that which was lost by natural causes. Chlorosis was corrected by applications of soluble forms of iron, as sprays or injections.

It is proposed that thiocyanates may unite with iron in the skins of apple fruits rendering the iron unavailable for synthesis of chlorophyll, which does not transmit blue-violet light. Chlorotic tissue permits the entrance of more blue-violet light to the epidermal and hypodermal tissues which are then able to produce more anthocyanin pigment.

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Relation of Spray Materials to Russeting of Delicious and Golden Delicious Apples[1]

(PRELIMINARY REPORT)

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RUSSETING of apple fruits occurs to some extent almost every year in the Hudson Valley but in 1940, 1942, and 1943 growers of such dessert varieties as Delicious and Golden Delicious suffered considerable loss from this type of injury. Fortunately, russet injury on McIntosh is usually not a problem if wettable sulfur fungicides are used.

Low temperatures before or during bloom have been reported as the cause of russeting of apples (3). Similar injury has been caused by spray materials especially Bordeaux mixture or liquid lime-sulfur with arsenate of lead, but wettable sulfur mixtures also caused some russet (1). Those who have worked on this problem would probably agree that other factors such as wet weather or high relative humidity at the time of spray applications, air and soil drainage, and tree nutrition may at times be contributing causes. Although wettable sulfur products have largely replaced lime-sulfur and copper fungicides on apples in the Hudson Valley, russet injury remains a problem partly because arsenate of lead is still required for insect control.

Fungicidal tests started in 1941 with Fermate (ferric dimethyl dithiocarbamate) for the control of apple diseases indicated that fruit and foliage sprayed with this material were injured less than those sprayed with lime-sulfur or wettable sulfur. Accordingly experiments were initiated in 1943 to determine to what extent this organic fungicide used with arsenate of lead might avoid russet injury on Golden Delicious.The results of one season's work are presented as a preliminary report for the benefit of others interested in this problem.

FIELD OBSERVATIONS

The severity of fruit russet on Delicious and Golden Delicious varieties in 1943 was determined by a survey conducted with the aid of assistant county agents in three Hudson Valley counties (Table I). A total of 56 orchards including experimental plots were visited. In 26 of these the injury was severe, in 14 russet was moderate, and in 6 it was slight. Ten Delicious orchards showed no russet injury. Nine of these had received no sprays or dusts and the other one had received Fermate as the fungicide throughout the season. None of the 19 Golden Delicious orchards observed were entirely free of russet. Unsprayed trees of this variety showed slight injury on high ground with good air drainage and moderate to severe injury at lower elevations in the same orchard where air drainage was poor and the trees remained wet following rains. A minimum temperature of 27 degrees F occurred in one Golden Delicious orchard during early bloom and

[1]Journal Paper No. 597 of the N. Y. State Agricultural Experiment Station.

TABLE I—OBSERVATIONS ON RUSSETING OF DELICIOUS AND GOLDEN DELICIOUS APPLES IN THE HUDSON VALLEY IN 1943*

Fungicide Treatment**	Variety	No. of Orchards with Stated Degrees of Russet				
		No Injury	Slight Injury	Moderate Injury	Severe Injury	Total Orchards
Unsprayed	Delicious	9	0	0	0	9
Unsprayed	Gold Del	0	1	1	2	4
Wettable sulfur	Delicious	0	1	3	10	14
Wettable sulfur	Gold Del	0	1	3	3	7
Flotation paste	Delicious	0	1	1	3	5
Flotation paste	Gold Del	0	0	2	2	4
Liquid lime-sulfur	Delicious	0	1	1	3	5
Fermate	Delicious	1	0	0	0	1
Fermate	Gold Del	0	1	1	0	2
Sulfur dust	Delicious	0	0	0	2	2
Sulfur dust	Gold Del	0	0	1	0	1
4 per cent Fermate-sulfur dust	Delicious	0	0	0	1	1
4 per cent Fermate-sulfur dust	Gold Del	0	0	1	0	1
Totals		10	6	14	26	56

*The results of a survey conducted in Dutchess, Ulster, and Columbia counties with the aid of assistant county agents: A. T. Williams, C. C. Gillette, and W. H. Palmer.

**Arsenate of lead and lime 3–3–100 were included with sulfur treatments. Fermate was used with arsenate of lead or summer oil and nicotine with no lime. The dust mixtures contained 20–25 per cent arsenate of lead.

probably increased the amount of russet at the lower elevations since the minimum temperature at an elevation 50 feet higher was 33 degrees F. Freezing temperatures were not a factor in the other orchards under observation.

In sprayed orchards, Delicious were more severely injured than Golden Delicious receiving the same spray treatment this season. All sulfur-arsenate of lead combinations resulted in russet injury regardless of the form of sulfur or whether applied as sprays or dusts. A 4 per cent Fermate-sulfur-arsenate of lead dust caused as much injury as a sulfur-arsenate of lead dust. In orchards where Fermate was used as a spray, russet was absent on Delicious. On Golden Delicious the injury was no worse than that on unsprayed trees.

In an orchard where only the pre-bloom sprays were applied, russet was severe on Delicious, but Golden Delicious receiving the same sprays had no more russet than unsprayed trees. In two Delicious orchards no sprays were applied until petal-fall but russet injury was severe. This season frequent rains during both the pink stage and at petal-fall made it necessary for most growers to apply sprays in the rain or while the trees were still wet. In a few orchards observed these sprays were delayed until the trees were dry and less russet occurred in these cases.

FIELD EXPERIMENTS

To determine the part spray materials might play in the occurrence of fruit russet, Golden Delicious trees in the Red Hook and New Paltz sections of the Hudson Valley were used in the 1943 spray injury tests. In these experiments all materials were applied with a power sprayer operating at a pressure of 500 pounds.

Sprays were applied in the Red Hook orchard at the pink stage, in bloom, at petal-fall, and 10 and 30 days after petal-fall. The treat-

ments were randomized in a row of 25 trees. Twelve trees received Sulforon 5–100, eight received Fermate 1–100, and four received arsenate of lead and lime 3–3–100 in the petal-fall and cover applications. One tree was left unsprayed. Arsenate of lead 3–100 was used without lime in both fungicide treatments in the petal-fall and cover applications.

All trees in the New Paltz orchard were sprayed at the pink stage with Micronized sulfur and arsenate of lead 5–3–100. The experimental treatments were applied with no arsenical during bloom to control cedar-apple rust and quince rust. Arsenate of lead 3–100 was used with the fungicides at petal-fall and 12, 22, 34, and 53 days after petal-fall. In this orchard Micronized sulfur 5–100 was compared with Fermate 1–100 and Fermate 1–100 plus 1 pint of S. E. C. (a self-emulsifying cottonseed oil). The oil was added with the idea that it might protect the epidermal cells of the young fruit from the action of adverse weather or spray materials. Each treatment was applied to a full row of 20 trees which extended from the top of a ridge to a depression 25 to 30 feet lower.

The results of these experiments were taken at harvest by examining three or four bushels of apples from each count tree and averaging the results of several count trees in each treatment. Fruits free of russet were given a rating of 0 and the rest were classified according to the amount of russet into 10 classes, beginning with 1 for very slight russet and advancing to 5 for heavy russet on one half of the fruit, and to 10 for heavy russet over the entire apple. The amount of russet in classes 1 and 2 was scarcely noticeable, that in class 3 was noticeable but covered less than one quarter of the surface area and would pass as U. S. No. 1 grade. Classes 4–10 would be excluded from U. S. No. 1 grade.

Experimental Results

In the Red Hook orchard russeting was very severe. Fruit from unsprayed trees had some russet but insect and disease injuries caused most of the fruit to drop early and made it impossible to take accurate data.

Fruit from trees receiving only arsenate of lead and lime were less than 1 per cent free of russet, 25 per cent had slight russet (classes 1–3), and 75 per cent had severe russet (classes 4–10) (Fig. 1). Besides the russet injury 10 per cent of the fruit from these trees showed the black calyx type of arsenical injury.

Trees sprayed with Sulforon 5–100 plus arsenate of lead produced fruit with slightly more russet than that from trees sprayed with just the arsenical and lime. Ten per cent of the fruit from these trees also was injured by the calyx type of injury.

Fruit from trees sprayed with Fermate 1–100 plus arsenate of lead averaged 9 per cent free of russet, 62 per cent with slight russet, and 29 per cent with sufficient russet to exclude it from U. S. No. 1 grade. Besides reducing the amount of russet, the Fermate treatment also reduced the calyx end injury to less than one per cent. No

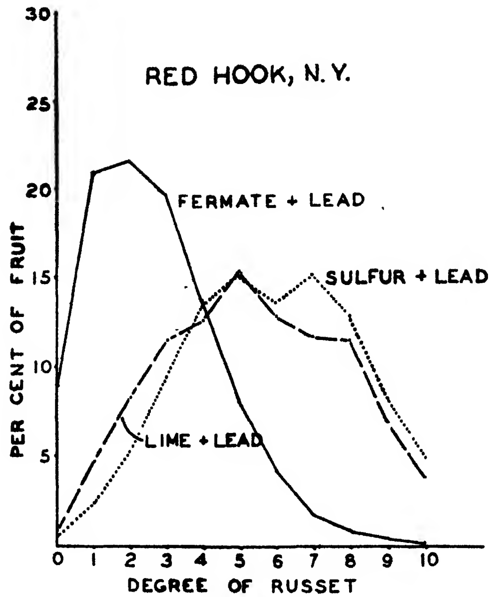

FIG. 1. The effect of spray materials on the russeting of Golden Delicious apples. (1943 season).

records were made of leaf injury but the Fermate sprayed trees appeared to have darker foliage and the trees in general appeared better.

In the New Paltz orchard the differences between the sulfur and Fermate sprayed trees were again easily noticeable. The trees at the high end of the rows showed relatively less fruit russet for each treatment than those at the low end. Records of the amount of injury on fruit from trees at three different elevations were taken for each treatment (Table II).

At the highest elevation, about 30 feet above the low point, the air drainage was good. Trees at this point sprayed with Micronized sulfur had only 25 per cent of the fruit free of russet compared with 73 and 79 per cent russet-free fruit on trees sprayed with Fermate and Fermate plus S. E. C. respectively. Fruit from the same trees which would pass U. S. No. 1 grade with regards to russet in the same order were: 82, 98, and 98 per cent respectively.

TABLE II—THE EFFECT OF SPRAY TREATMENTS AND ELEVATION ON RUSSET INJURY OF GOLDEN DELICIOUS. NEW PALTZ, N. Y. 1943

Treatment	Elevation*	Fruit of U. S. No. 1 Grade			Fruit Below U. S. No. 1 Grade Due to Severe Russet (Per Cent)
		No Russet (Per Cent)	Slight Russet (Per Cent)	Total (Per Cent)	
Micronized sul plus arsenate of lead 5-3-100	High	25.0	56.5	81.5	18.5
	Medium	14.2	51.3	65.5	34.5
	Low	6.0	45.7	51.7	48.3
	Average	15.1	51.2	66.3	33.7
Fermate plus arsenate of lead 1-3 100	High	73.4	24.9	98.3	1.7
	Medium	36.5	48.4	84.9	15.1
	Low	27.4	52.2	79.6	20.4
	Average	45.8	41.8	87.6	12.4
Fermate plus arsenate of lead 1-3-100 and SEC 1 pt	High	78.5	19.7	98.2	1.8
	Medium	41.7	52.5	94.2	5.8
	Low	30.5	59.3	89.8	10.2
	Average	50.2	40.6	90.8	9.2

*The difference in elevation between the high and low points was about 30 feet.

On the slope of the ridge near the center of the rows the percentages of fruit free of russet on the trees sprayed with sulfur, Fermate, and Fermate plus S. E. C. were: 14, 37, and 42 respectively. That which would pass U. S. No. 1 grade for the three treatments in the same order were: 66, 85, and 94 per cent. Fruit at the low end of the rows sprayed with sulfur averaged only 6 per cent free of russet, 52 per cent passed U. S. No. 1 grade and 48 per cent was below this grade. In contrast fruit from the Fermate row had only 20 per cent below No. 1 grade and where S. E. C. oil was added this was only 10 per cent.

Discussion and Conclusions

The results of observations in commercial orchards and experimental plots indicate that part of the severe russet which occurred on Golden Delicious and almost all of that on Delicious apples in 1943 was the result of spray injury. The 1943 season was one with an unusual amount of rainy weather from the green-tip stage of apple development through the petal-fall stage. The almost continuous rains made it necessary for growers to apply sprays while the trees were wet and conditions were unfavorable for quick drying. Under these circumstances russet injury was more severe than it has been in drier seasons. The fact that trees on high ground with good air drainage suffered less than those at lower levels might be explained by the more rapid drying of the former following rains and spray applications.

Fruit russet on Delicious in 1943 appeared to be almost entirely a result of spray injury since no russet was found on unsprayed trees regardless of elevation. In contrast practically every sprayed orchard showed considerable russet where sprays were applied under wet conditions. The one exception was an orchard which had received Fermate as the fungicide throughout the season. Golden Delicious on the other hand often showed a high percentage of fruit with slight russet even on unsprayed trees. However, where sulfur-arsenate of lead sprays were applied the injury was increased and was of a more severe type. The use of Fermate on this variety did not eliminate all of the russet but prevented an increase over that on unsprayed trees.

Arsenate of lead without any fungicide caused almost as much russet on Golden Delicious as the combination of wettable sulfur and arsenical, indicating that at least part of the injury is due to the arsenical. The reduced amount of russet where Fermate was used with the arsenate of lead indicates a corrective action by the Fermate when used as a spray. The fact that calyx end injury was also reduced in the Fermate plots further substantiates this view. Further investigations on this point are in progress.

The critical period for russet injury in 1943 appeared to be from the pink stage till two or more weeks after petal-fall. Since this is also the critical period for disease development in the Hudson Valley, Fermate 1 or 1½–100 applied at the pink, bloom, and petal-fall stages and ten days following petal-fall could fulfill the double role of avoid-

ing fruit russet and still provide adequate protection against fungus diseases. Recent experiments (2) have shown that Fermate is much more specific than sulfur in controlling quince rust, *Gymnosporium clavipes* C. and P., which is bad on both Delicious and Golden Delicious; and Cedar-apple rust, *G. juniperi-virginianae* Schw., to which the latter variety is very susceptible. It has also been shown that Fermate will control apple scab (2).

The value of adding cottonseed oil (S. E. C.) to the Fermate treatment to further reduce russet injury has been indicated but the nature of its action and its practical value require further study. Fruit from the plots receiving the cottonseed oil was improved in appearance as it had more luster than that from the other plots.

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Some Physiological Responses of Deciduous Fruit Trees to Petroleum Oil Sprays[1,2]

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Petroleum oils have long been recognized as effective insecticides and have been used extensively for this purpose in the treatment of deciduous fruit trees, especially during the dormant or semi-dormant period. Since there are limits to the amount of oil even dormant trees will tolerate, the dosage applied to a tree is controlled by applying the oil in the form of an emulsion, and by utilizing only the minimum concentration required for insect control. A general investigation of oil sprays was started at this Station in 1939. Reports appearing to date (2, 3, 7, 8) on this project have considered the insecticidal action of the oils. The present paper is a report on the response of the tree to these treatments. The respiratory response exhibited by plant tissues which have received mechanical injury or treatment with toxic or anaesthetic materials suggested that a study of the effect of such sprays on the respiratory activity of treated trees might be of value in determining the nature of the injury.

Various toxicants have been combined with dormant oils to provide control of certain pests such as the aphids for which oils alone are not effective. The best example of such products, at present, are the dinitro compounds, principally 4, 6 dinitro-o-cresol and its salts. Reports from growers and research workers are variable as to the phyto-toxic effects of the dinitro-oil combination. Severe bud and wood injury has occurred in some instances. But the fact that it is often possible to apply this mixture safely suggests that harmful effects might be avoided if the nature of the physiological response involved could be determined. As a part of the general study of the tree response to oil sprays, therefore, some observations are included on oil sprays containing dinitro compounds.

In New York, oil sprays are commonly applied to fruit trees during the latter half of March and in April. Orchards may be treated before green tissue shows, although within recent years there has been an increasing tendency to apply these sprays after new growth appears, continuing until leaves in blossom buds are exposed a half inch or slightly more. The most common effect noted where oil sprays are applied to apple trees late in the dormant period in the spring is a delaying of bud growth. Usually this effect is quite transitory. It may not even occur if the oil content of the spray is moderate or low. While such retardation of bud growth by oil sprays generally does not appear to cause any real harm, cases have been reported where damage has occurred following the application of maximum oil concentrations. This injury has taken the form of weakening to an outright killing of

[1]This is paper No. VI in a series appearing originally under the general title "The use of petroleum oils as insecticides".

[2]Journal Paper No. 591, New York State Agricultural Experiment Station, Geneva, New York.

the buds. Shoot buds that have been "weakened" by oil produce a limited growth, while blossom buds thus involved are so reduced in vitality that few, if any, fruits are set. On oil injured trees the more serious damage will be found on the lower limbs and other shaded growth in the interior of the tree.

Materials and Methods

The oils used in this investigation are representative of the various kinds that either have been used in dormant spraying or should be included to cover various types available based on composition. Some data on their properties are given in Table I. Oils A3, A5, I1 and I4 are distinctly "paraffinic" in character, A1 is derived from a mid-continent source and thus is an "intermediate" type, while D1, D3 and D6 are so-called "naphthenic" class oils.

TABLE I—Properties of Petroleum Oils Used*

Oil No.	Saybolt Universal Viscosity (Seconds at 100 Degrees F)	Kinematic Viscosity Index (A.S.T.M.)	Gravity API Degrees at 60 Degrees F	Density**	Aniline Point (Degrees C)	Unsulfonated Residue (A.O.A.C.) (Per Cent)	Specific Dispersion at 20 Degrees C (Gladstone Dale ×10⁴)
D1	120 2	-4	21.8	0.9189	67.0	62	129
D3	84.3	53	28 4	0 8800	91 4	90	94
A1	105 6	63	27.8	0.8842	82 8	66	128
I1	99.8	90	31 6	0 8626	94.0	68	115
A3	100.9	115	34.2	0 8502	104 4	86	102
A5	98.4	105	34 2	0.8502	106.2	98	97
D6	206.3	16	21.5	0.9209	71.5	62	130
I4	171.0	104	31.7	0.8630	104 1	67	110

*For a discussion of the significance of the data shown, see Pearce, Chapman and Avens (8).
**Density at 20 degrees C referred to water at 4 degrees C.

A commercial dinitro powder was used which contained 40 per cent of the toxicant as 4, 6 dinitro-o-cresol. Boyce and his coworkers (1) have shown that with the related compound 2, 4 dinitro-o-cyclohexylphenol the toxicant occurs predominately in the oil phase in an acid medium, migrating sharply to the aqueous phase when the medium is alkaline. As might be expected, a similar behavior for 4, 6 dinitro-o-cresol was found. With this point in mind, the pH of the spray water was varied to determine the possible effect on tree injury of varying the toxicant between the oil and water phases of the spray mixture.

All of the oils were applied to the trees in the form of emulsions using a standard type power orchard spraying machine. Emulsification was accomplished in the spray machine immediately before the application of the test lots, using blood albumin as the emulsifying agent at the rate of 2 ounces per 100 gallons of finished spray mixture. A description of the emulsifying technique used is given by Chapman, Pearce and Avens (2). The spray was applied through a single-nozzle spray gun at the approximate rate of 12 gallons per minute and with a pump pressure of 450 pounds per square inch. All the treatments were applied as "dormant sprays", that is, after the buds had swollen but before they had opened to show green.

The trees used in the 1942 trials were of two growth classes. The McIntosh and Rhode Island Greening trees used to secure the data in Table II were 13-year-old trees which had been given severe annual pruning. As a result, exceptionally vigorous growth had been made in the preceding season. Many terminals of 30 or more inches in length were produced. No fruit buds were in evidence. The Northern Spy trees in Table III were probably 30 years of age and in healthy condition. However, because of lack of care the vegetative growth was limited. The Elberta peach trees in Table IV were 5-year-old trees of good vigor and growth. Due to a severe freeze in December, 1942, all fruit buds were dead. However, the apparent injury on the wood was limited to several inches of the tips of the twigs. The trees of Rhode Island Greening and Twenty Ounce in Table IV were 12-

TABLE II—THE EFFECTS OF VARIOUS DORMANT OIL SPRAYS AND CONCENTRATIONS ON THE RESPIRATORY ACTIVITY OF TWIGS OF MCINTOSH APPLE TREES SPRAYED APRIL 14, 1942

Oil No.	Oil Conc. (Per Cent)	Per Cent Change in Respiratory Activity			Visual Injury Score 5/1	Initial Oil Deposit (Mg/Sq In)
		Apr 14	Apr 20	Apr 28		
D1	2	−10.8	−23.9	−12.8	9 0	1.42
D1	4	−10.0	−23 8	−26.2	5.5	3 17
D1	6	− 7.8	−27.9	−42.7	2.0	5.58
D1	8	−10.3	− 18.9	−45.5	0.0	8.22
A3	2	−11.2	− 9.2	−20.3	8.5	0.79
A3	4	−17.6	−15.8	−42.6	5.5	2.69
A3	6	−20.8	−17.2	−52.8	3.5	3.72
A3	8	− 16.6	− 14.4	− 49.9	2.0	5.23
I1	4	−10.3	−28.5	−34.8	4.5	3.10
I1	6	−12.3	−23.8	−43.9	1.0	4 54
I1	8	− 6.6	−14.1	− 42.8	0.0	4.68
A5	4	− 2.2	−11 8	−33.6	6.0	3.43
D3	4	−12 4	−13.0	−34 5	5.0	3.64
A1	4	− 15.7	− 11.8	−44 9	3.5	3 87
A1	4*	−17.7	− 6.6	−31 5	5 0	—
A1	4**	+39.3	− 4.4	−43 4	3.0	—
Control†	-	6.60	7 82	9.10	10	—

*On Rhode Island Greening.
**2 pounds of commercial dinitro-o-cresol powder added per 100 gallons spray.
†Mgs CO_2 evolved per gram of twig.

TABLE III—THE EFFECTS OF DORMANT PETROLEUM OIL SPRAYS ON MATURE NORTHERN SPY TREES SPRAYED APRIL 17, 1942

Oil No	Oil Conc. (Per Cent)	Per Cent Change in Respiratory Activity			Visual Injury Score 5/4	Initial Oil Deposit (Mg/Sq In)
		Apr 17	Apr 23	Apr 24		
D1	2	− 8.7	−24.6	+ 7.1	8	1.04
D1	4	−13.1	−21.1	− 3.3	8	2.29
D1	6	− 9.8	−23.3	−15 3	8	2.87
D1	8	− 1.0	− 19.2	−29.9	7	3.32
I1	2	− 6.7	−14 3	−15.1	8	1.06
I1	4	+ 6.2	18.4	− 27.9	8	1.97
I1	6	− 8.2	−20.2	−26.6	6	3.07
I1	8	−13.6	− 8.7	−23.6	6	3.88
I4	3	− 8.2	−24.7	−28.8	7	1.35
I4	6	− 5.4	−22.8	−29.4	6	2.98
D6	3	−21.8	−27.2	−21.7	8	1.81
D6	6	− 5.4	−22.4	−30.1	8	3.50
Control*	-	3.89	5.88	6 88	10	—

*Mgs. CO_2 evolved per gram of twig.

TABLE IV—RESPIRATORY ACTIVITY OF ELBERTA PEACH TWIGS SPRAYED WITH PETROLEUM OIL A1, MARCH 31, 1943

Oil Conc. (Per Cent)	Per Cent Change in Respiratory Activity			
	Apr 2	Apr 7	Apr 15	Apr 23
1	+5.6	-1.0	-10.0	-5.7
2	+8.6	-3.3	-15.4	-7.4
3	-4.3	-3.8	-17.4	-15.5
4	-4.6	-0.5	-1.8	-12.1
Control*	7.64	7.84	10.47	11.48

*Mgs. CO_2 evolved per gram of twig.

year-old trees in a well cared for commercial orchard. The Rhode Island Greening trees used in 1944 (Table VI) were the same ones used in 1942 (Table II).

The plant material selected for respiration studies consisted of wood of the previous year's growth. Twigs of comparable length and diameter were cut and taken to the laboratory. There a median section, 5 inches in length, was cut from each twig. In the earlier trials each sample consisted of 25 twigs but in the later runs this number was reduced to 15. The samples of cut twigs were placed in hardware cloth baskets which in turn were suspended in sealed respiration chambers consisting of wide mouthed Erlenmeyer flasks of 1-liter capacity. Each flask contained sufficient 0.5N sodium hydroxide solution to absorb the carbon dioxide evolved. The samples were held in constant temperature cabinets at 30 degrees C for 24 hours. At the end of this time the twigs were removed from the flasks, the carbonate precipitated with barium chloride solution, and the excess sodium hydroxide determined by titration with standard hydrochloric acid solution using phenolphthalein as indicator. It is realized that the data on CO_2 production thus obtained are not a measure of actual respiratory activity. But for the purposes of this paper they are considered as representing the "apparent respiration".

Rates of respiration were calculated on the basis of the fresh weight of the samples in terms of milligrams of carbon dioxide evolved per gram of twig in 24 hours. Respiration trials were run on samples collected a few hours after the spray dried and at approximately weekly intervals thereafter. Samples of wood were collected for oil and 4, 6 dinitro-o-cresol deposit determinations. The method employed for oil deposits is described by Pearce, Avens and Chapman (7). The dinitro-o-cresol was determined by extraction from the wood with petroleum ether and subsequent analysis in a photoelectric colorimeter. The first few trials in 1942 were run on duplicate samples taken from the treated and control plots. The duplicate samples gave results so nearly identical that thereafter duplicates were run on the control plots only. At the full "pink" stage of bud development, 18 days after spraying, the plots were inspected and scored on the basis of visual injury. The unsprayed check plots were given a rating of 10 to represent normal development. The treated plots were scored on the basis of 10 to 0 depending on the amount of injury.

Results

The data in Table II show that the oil sprays decreased the rate of respiration in practically all cases. In general the decrease in respiration was in direct relation to the amount of oil deposit. It should be mentioned that the initial oil deposits on this lot of material are higher than would normally be expected from sprays of the oil contents used in this experiment. (See Table I in Chapman, Pearce and Avens (3) and Table III of present paper). This was assumed to be due to the fact that the abnormally long twig growth of this lot of heavily pruned trees was covered with much heavier and more persistent pubescence than twigs from trees making more nearly normal growth. The visual injury appeared in the form of retardation of the lateral buds. Six days after application of the sprays it was noted that the lateral buds of the sprayed plots showed less indication of starting growth than the lateral buds of the control plots. Two weeks after spraying, at which time nearby mature McIntosh trees had reached the pre-pink stage, it was evident that the degree of retardation of development of the lateral buds was closely correlated with increasing oil content of the sprays. No consistent differences in tree response were detected among the various oils tested (Table I).

The appearance of growth in the plots receiving the series of oil concentrations is shown in Fig. 1. At this time nearby mature McIntosh trees were in full bloom. The effects shown are extreme, owing apparently to the heavier than normal oil deposits present and to the abnormal succulence of the growth. In any event, one should not gain the impression that retardation to this degree is typical either for the oil concentrations tested or where growers apply dormant oil sprays. An oil concentration of 4 per cent is the maximum strength advised at present in New York. No evidence of injury other than retardation was noted among these trees and by 6 weeks after spraying, the trees with retarded bud development appeared to have caught up with unsprayed plots.

Attention should be called to the fact that the decreases in respiratory activity shown by the sprayed material became more pronounced as the season progressed. This is attributed to the fact that by 2 weeks after spraying, appreciable amounts of leaf tissue had been produced by the buds on unsprayed twigs. The presence of such highly active tissue on the controls, of course tends to exaggerate the difference between the respiratory activity of sprayed and unsprayed plots. The respiration of such material admittedly becomes progressively more active as development proceeds. In view of that fact it is evident that comparisons of the respiratory activity of the various plots showing varying degrees of development on any one date is comparable to comparing the respiration of the same plot at different stages of development.

Table III presents the data from the plot of mature Northern Spy trees sprayed in 1942. Whereas the retardation and bud killing caused by the oils were readily visible on the McIntosh and Rhode Island Greening trees of Table II, the Northern Spy trees showed little

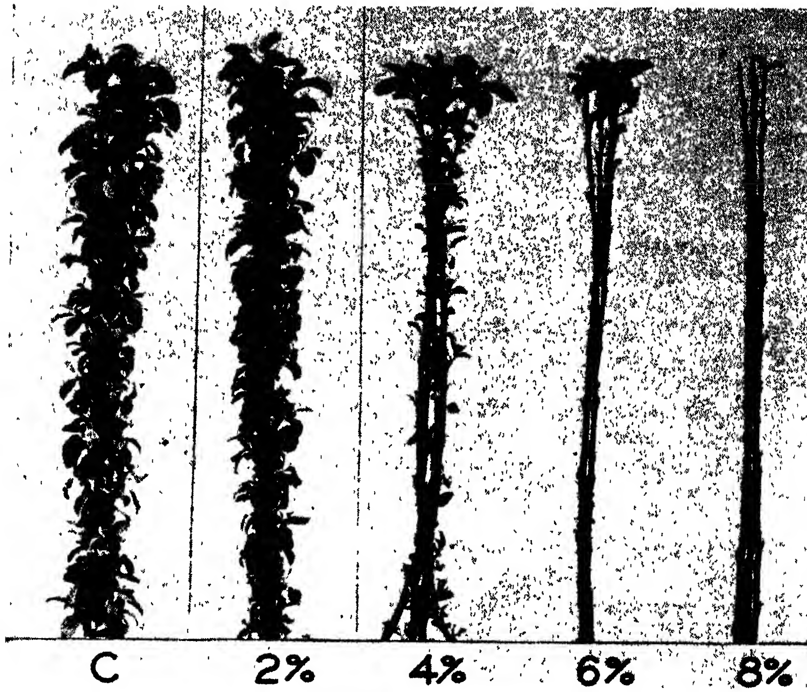

FIG. 1. Response of overly vegetative McIntosh apple trees treated with oil sprays of varying oil content compared with an untreated plot (C). 1942.

outward evidence of treatment except for a moderate retardation which varied little between the sprayed plots. However, the rate of respiration of the sprayed material was again immediately reduced to less than that of the unsprayed material. The heavier concentrations of oils showed a tendency toward greater depression of the respiratory rate but the relationship was less striking than it was in the case of the material listed in Table II. At least a partial explanation of this effect is that the initial oil deposits per square inch of twig surface were appreciably lower than on the more pubescent twigs of the overly vegetative McIntosh and Rhode Island Greenings.

The data in Table IV indicate that peach twigs have similar responses to oil sprays. The decreases in the rates of respiration were not so great as in the case of apples but the oil concentrations of the sprays applied were lower. The peach trees were very slow in starting visible growth due to the cold, delayed spring. However, by the time growth started the sprayed trees did not appear to be more retarded in development than were the control plots.

A feature of the tree response to the oil-dinitro sprays was the greatly increased initial rate of respiration exhibited (Table V). This accelerated rate was still evident 1 week and 2 weeks after spraying though to lesser degree and with some irregularity. Three weeks after

spraying the changes in the respiratory rate of the sprayed material had all assumed a negative value.

The terminal growth in several of the plots of the 1942 experiment are shown in Fig. 2. This illustrates an effect noted both by growers and investigators in some orchards where a dinitro compound is used with oil. Someone has termed the condition "mule-tailing." It should be pointed out again that many growers in New York have applied the oil-dinitro spray combination without producing this effect. In fact, the writers have been unable to produce this injury under normal orchard conditions in 4 years of experimentation even though maximum strength of oil and the dinitro preparations were employed.

An important factor operating in 1943 was the rapid removal of the dinitro deposit by rainfall. According to analyses made of twig samples, not more than 10 per cent of the original deposit remained at the end of 2 weeks and within 4 weeks practically all of the dinitro compound had weathered away. Since the visible effects of treatment were so slight and variable, it was concluded that attempts to score the treatments on the basis of visible injury would have been of little or no value. At the full bloom stage, 6 weeks after spraying, all treated plots appeared to be as well developed as unsprayed plots.

FIG. 2. Untreated Rhode Island Greening growth (C) compared with terminals from plots receiving oil and oil-dinitro (DNOC) sprays. 1942.

Although the visible effects of treatment were small in the 1943 experiment, the respiration data suggest that the trees receiving Treatment 9 showed the greatest initial and sustained response to the oil-dinitro combination (Table V). This is in line with expectation because of the distinctly acid nature of the spray water. Under such conditions the maximum amount of the dinitro product should be carried in the oil, as pointed out by Boyce *et al* (1). This supposition was confirmed by data from twig analysis which showed that on trees receiving Treatment 9 the initial dinitro deposit was nearly twice that of any other plot.

TABLE V—Respiratory Activity of Apple Twigs Given Dormant Oil Sprays April 9, 1943

Treatment No.	Oil No.	Oil Conc. (Per Cent)	Other Materials Added per 100 Gallons Spray	Per Cent Change in Respiratory Activity							
				Twenty Ounce				Rhode Island Greening			
				Apr 12	Apr 20	Apr 30	May 4	Apr 12	Apr 20	Apr 30	May 4
1	A1	4.0		− 2.6	− 9.0	− 6.0	−14.9	− 2.6	− 0.9	+ 2.8	−26.5
3	A1	4.0	2 pounds dinitro powder + ½ pound hydrated lime	+30.5	+ 2.1	− 2.8	− 5.4	+22.6	+ 8.1	+14.4	− 9.4
4a	--	--	2 pounds dinitro powder + ½ pound hydrated lime	+20.1	+ 3.5	+ 6.5	−11.5	+23.2	+ 0.4	− 0.9	−16.2
4b	A3	2.5	Applied over 4a April 13	——	−4.9	− 7.6	−18.0	——	+33.1	+14.0	−11.8
5	A1	4.0	2 pounds dinitro powder + 2.8 ounces NaOH	+18.4	− 1.4	+ 6.0	− 3.6	+19.9	+15.3	+ 5.6	− 7.7
9	A1	4.0	2 pounds dinitro powder + 9 ounces oxalic acid	+24.3	+32.2	+11.3	− 7.1	+23.7	+16.4	+ 8.6	−22.8
			Control*	5.77	5.75	6.17	7.57	5.42	5.55	5.70	8.08

*Mgs. CO_2 evolved per gram of twig.

The responses of the highly vegetative Rhode Island Greening trees sprayed in 1944 are shown in Table VI. The effect of the 4 per cent oil spray was similar to that produced in 1942 and 1943. Appreciable decreases in respiration were measured and marked retardation of development was noted. The addition of the dinitro powder to the spray produced immediate sharp increases in respiratory activity in all cases. The increase in respiration was particularly marked in the plot sprayed with the acidified spray emulsion (Treatment 7). In all cases in which the dinitro powder was added to the emulsion the increase in respiratory activity shown by the twigs was of short duration and by 5 days after spraying had changed to a decrease. An explanation for this fact may be found in the data on oil and dinitro deposits given in Table VII. These data show that by 5 days after

TABLE VI—The Respiratory Response of Rhode Island Greening Apple Trees Sprayed April 19, 1944

Treatment No.	A1 Oil Conc. (Per Cent)	Other Materials Added per 100 Gals Spray	Per Cent Change in Respiratory Activity				
			Apr 19	Apr 24	Apr 28	May 2	May 6
1	4.0	————	− 1.9	− 2.8	−12.7	−15.4	− 3.4
2	4.0	2 pounds dinitro powder	+27.7	− 4.9	−16.9	− 0.1	− 5.8
3	4.0	2 pounds dinitro powder + 13 ounces com. lye (NaOH)	+27.8	− 5.9	− 8.4	− 5.9	+13.8
4	——	5 ounces oxalic acid	+ 8.4	+ 3.8	−13.1	+ 2.9	+ 6.2
6	4.0	13 ounces com. lye (NaOH)	− 3.5	− 6.4	−10.6	−15.3	+ 0.9
7	4.0	2 pounds dinitro powder + 5 ounces oxalic acid	+50.8	− 2.8	−14.6	−26.0	−32.3
8	12.0	————	+24.4	+13.6	− 2.9	−12.4	−37.4
9	25.0	————	+3.1	+11.7	+ 8.7	− 9.3	−37.1
		Control*	6.42	6.90	7.85	8.88	9.63

*Mgs CO_2 evolved per gram of twig.

spraying, during which interval three showers totaling 1.05 inches had fallen, nearly all of the dinitro material had been removed. They also show that the deposition of dinitro material in the acidified spray (Treatment 7) was approximately twice that of either the alkaline spray or the untreated spray mixture. Treatments 8 and 9 which contained 12 per cent and 25 per cent of oil respectively produced increases in respiration immediately after application. These increases were of longer duration than the increases noted in the treatments containing the dinitro compound. The data on oil deposition show that the deposits on plots 8 and 9 were several times heavier than on any other plot. In fact after nearly 3 weeks exposure to the elements, the

TABLE VII—The Influence of Weathering and Time on the Disappearance of Oil and Dinitro Deposits on Rhode Island Greening Trees Sprayed April 19, 1944

Treatment No.	A1 Oil Conc. (Per Cent)	Other Materials Added per 100 Gals Spray	Oil Deposits in Mg/Sq in					DNOC Deposits in Mmg/Sq in			
			Apr 19	Apr 24	Apr 24	May 2	May 5	Apr 19	Apr 24	Apr 28	May 2
1	4.0	———	2.71	1.67	1.25	0.86	0.80	—	—	—	—
2	4.0	2 pounds dinitro powder	1.84	0.87	0.85	0.47	0.41	38.2	1.5	1.9	0.9
3	4.0	2 pounds dinitro powder + 13 ounces com. lye (NaOH)	1.55	0.91	1.02	0.52	0.39	43.8	1.3	0.8	0.0
6	4.0	13 ounces com. lye (NaOH)	1.66	—	0.80	0.65	0.43	—	—	—	—
7	4.0	2 pounds dinitro powder + 5 ounces oxalic acid	2.39	1.53	1.23	0.74	0.75	72.6	3.4	3.0	0.0
8	12.0	———	7.36	4.53	3.38	2.85	3.11	—	—	—	—
9	25.0	———	10.97	7.02	6.21	4.80	4.69	—	—	—	—

oil deposits on plots 8 and 9 were nearly twice as heavy as the original deposits on any of the plots sprayed with 4 per cent oil. These overdoses of oil are of interest in that, while they were far heavier than the maximum oil concentrations recommended for use in this state, they did not cause as severe injury to the trees as had been anticipated. There was marked delay in development, of course, and some killing of twig terminals as well as lateral buds. However, by two months after spraying the trees had made fairly satisfactory new growth.

In 1943 and 1944 a study was made of the penetration of the spray oils into the twigs. The method and differential staining technic described by Rohrbaugh (9) was found the most satisfactory of several used. This method involves cutting sections of fresh material, killing in Bouin's solution and staining in a combination of nile blue sulfate and Oil Red 0 solutions. This combination dye stains the natural oils and fatty materials dark blue, black, or brown and the petroleum oils a bright scarlet red. Numerous twig sections were cut and stained at periods of 2 to 4 weeks after spraying. The sections were made at the nodes and at various locations between the nodes. The sections cut between the nodes in only a few instances showed deposits of oil and those deposits were only traces in the corky tissues of the lenticels or mechanically injured areas in the bark. In these cases the oil did

not penetrate the adjoining tissues beyond one or two layers of cells. At the nodes, however, large quantities of oil had accumulated. Sections made a week after spraying showed the oil to be mostly in the form of large blobs and droplets lying between the bud scales and rudimentary leaves. The cells of the bud scales contained oil in some cases. Sections cut 10 days after spraying showed that the oil had penetrated the bud tissues. Large quantities were found in the bud meristems. Many of the cells were saturated with oil. The oil seemed to move from the bud tissue along the leaf traces and to some extent along the branch traces to the vascular cylinder. During the stages of development studied no extended movement of the oil into the vascular cylinder was observed. Rohrbaugh (9) working with citrus found that under the usual condition of application there was no evidence that oil enters cells which contain protoplasm. The cells of the bud meristems of the material included in this study often were saturated with oil as were some of the cells in the phloem tissues below the buds.

It may be noted here that the tips of many of the leaflets which developed on twigs receiving the oil-dinitro sprays showed marginal injury. In sectioning retarded buds of this material numerous instances of injured leaf primordia were observed. Such sections contained larger amounts of oil and showed more extensive penetration. The injury observed on the leaflets no doubt occurred while the buds were still unfolded. It seems highly probable that the injury was caused by the dinitro material and that both entrance and penetration by the oil may have been facilitated by such injury.

Twigs which received applications of 12 and 25 per cent oil sprays in 1944 (Treatments 8 and 9) showed extensive penetration of the oil into the wood between the nodes as well as at the nodes. A week after the spray was applied, oil was found throughout the phloem. Three weeks after spraying, small twigs, and especially the softer wood near the tips, showed accumulation of oil in cells lying just outside of the pith.

Discussion

The data on the respiratory activity of the sprayed material lead to several conclusions. All sprays containing only oil in concentrations of the maximum recommended dilutions produced immediate decreases in the rates of respiration. Only in the case of the 12 and 25 per cent oil sprays applied in 1944 were increases in respiration observed. The oil deposits on the twigs receiving the heavy concentrations of oil were much greater than the deposits on twigs receiving sprays of recommended maximum concentration but were only slightly heavier than the deposits obtained from an application of 8 per cent oil applied in 1942 which produced a decrease in respiration. The oil and dinitro combinations, on the other hand, produced immediate increases in respiratory activity. The increases were of extremely short duration and were usually replaced by decreased rates after a few days. The dinitro materials are soluble in water and would undoubtedly be removed by rainfall. The analyses for deposits of this material presented in Table VII show this to have been the case.

Kelley (6) found that applications of oils before the buds had begun to swell produced increases in respiration, whereas when the same oils were applied after the buds had burst they caused reductions in the rates of respiration of apple twigs. The stage of development at the time of application beyond question played no part in the results presented here inasmuch as all sprays were applied after the buds had swollen. Fruit growers of this area normally apply "dormant" sprays at this stage of development. No variations in the stage of development at the time the sprays were applied were noted in any of the trees of the various plots receiving treatment. Knight, Chamberlin and Samuels (5) found that applications of a highly refined, undiluted, white oil on citrus trees caused immediate enormous increases in respiratory activity which persisted for a long time after spraying. Green and Johnson (4) reported that bean leaves sprayed with dark, undiluted petroleum oils, high in unsaturated compounds, showed increased respiration rates, whereas the application of light colored oils low in unsaturates decreased the rates of respiration to less than those of the controls. The response of plants in full leaf to applications of undiluted oils might well be expected to be unlike the response of woody material in a more or less dormant condition, considering also that in this latter instance relatively dilute emulsions were employed.

The study of sections of twigs receiving sprays of recommended maximum oil concentrations revealed that the oil accumulated primarily in and near the buds. It is highly probable that retardation of the lateral bud development is a localized effect resulting from these accumulations of large quantities of oil within and near the buds. Whether the retardation is the result of mechanical interference with gaseous exchange or of cell poisoning cannot be stated here.

These histological findings do suggest an explanation of lateral bud killing which may occur after oil-dinitro insecticide sprays are applied. The dinitro compounds are partially soluble in petroleum oils especially in an acid medium. Consequently, the toxicant would be carried with the oil into the buds and thus be brought in contact with sensitive bud tissues. As to why the dinitro-oil combinations prove relatively safe in some instances and highly injurious to buds in others, the authors suggest this may be due in part to variations in bud vigor. Conditions promoting or delaying bud growth following treatment may also be factors. Another possibility is poor dispersal of the dinitro product in the spray-tank occasioned by using a faulty mixing technique. This would result in certain trees receiving an excessive load of oil and dinitro product.

Summary

The application of dormant petroleum oil sprays of varying oil content on apple trees was found to retard development of the new growth. The respiratory activity of the treated tissue was found to be less than that of untreated trees and was associated with increasing oil content of the sprays. The addition of a dinitro material to the oil spray also retarded development but produced pronounced increases in the rate of respiration of the trees immediately after spraying.

Sprays of an acid nature which carry the dinitro material predominantly in the oil phase of the emulsion were found to be more toxic to the plant tissue than neutral or alkaline sprays. The effect of the dinitro sprays was found to be of short duration since this material is readily removed by rainfall. Histological studies of sprayed material showed that the oil does not penetrate the plant tissue extensively except at the nodes during the period when retardation effects are most evident. The lateral buds and adjacent tissues of trees receiving oil sprays of recommended maximum concentrations contained large quantities of oil which undoubtedly were responsible for the retarded development and decreased respiration noted.

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Synthetic Organic Fungicides for Apples[1]

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CONCEPTS of pesticides are undergoing rapid change due to the collaboration between chemists and crop production men of public agencies and industry. The fortunate observations of P. A. Millardet in 1882 gave rise to Bordeaux mixture and those of P. J. Parrott, A. B. Cordley, and others about 1905–1906 to liquid lime sulfur as the most used fungicides for the past several decades. Today superior materials are becoming available because of the systematic creation of new compounds and the scientific evaluation of their pesticidal properties. Compounds are being formulated to meet specifications dictated by the tolerance of the host plant and the resistance of the pathogen or insect pest. Three groups of organic compounds; thiocarbamates, thiurams, and naphthaquinones, have already been tailored to fit the control requirements for certain diseases better than the inorganic sulfur, mercury and copper compounds previously used.

Members of two new generic groups of cationic organic fungicides: phenyl-mercuri (Puratized) and pyridine derivatives (Isothan Q) have experimentally given outstanding disease control on apples the past two seasons. The high fungicidal value of these materials is evident by the fact that, whereas ten pounds of wettable (Camden Paste) sulfur or one and one-half pounds of Fermate are used in 100 gallons of spray, about 20 grams of Puratized N5D toxicant or 78 grams of Isothan Q15 toxicant gave equal or better Apple Scab control. While these materials are used on plants at 1 : 20,000 or 1 : 5000 respectively, they have much higher potential fungicidal values. As determined by laboratory techniques, some will inhibit germination of test fungous spores 90 per cent or better when diluted to one part per million in water.

In the past the timing of fungicide applications has been a factor of prime importance because, with the exception of liquid lime sulfur, the materials have been used as particulate protectants. That is, microscopic particles of the compound were applied to the infection courts prior to inoculation rather than after infection may have occurred. These new organic fungicides, like the older ones, kill the spores during their vulnerable germination period. Several, unlike those now in common use, appear to arrest lesion development and sporulation to a high degree and therefore may be said to have therapeutic action. For example, McIntosh apple leaves bearing Scab *(Venturia inaequalis)* lesions were sprayed with Isothan Q15 *(lauryl isoquinolinium bromide)* at 1 : 5000 and Puratized N5D *(phenyl mercuri triethanol ammonium lactate)* at 1 : 20,000. As indicated in Table I, the Isothan Q15 suppressed sporulation in 77.2 per cent and the Puratized N5D in 76.9 per cent of the lesions. In addition to reducing the amount of potential inoculum, such fungicides also reduce

[1]Contribution No. 656 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

the amount of tissue injured on an individual leaf which permits a high photosynthetic level for the foliage. The comparative performance of several materials is shown by Table I.

TABLE I—INACTIVATION OF APPLE SCAB LESIONS ON McINTOSH FOLIAGE WITH FUNGICIDAL CHEMICALS

Material	Dilution	No. of Leaves	Active Scab Lesions	
			Before Treatment (No.)	After Treatment (Per Cent)
Season of 1943				
Puratized**	§1:1,000	10	45	−71.1*
Puratized**	1:5,000	10	55	−54.4
Puratized**	1:10,000	10	27	−29.6
Isothan Q4†	1:1,000	5	10	−60.0
Isothan Q4†	1:5,000	5	19	−31.6
Isothan Q4†	1:10,000	5	12	−25.0
Liquid lime sulphur	1:50	5	35	−71.4
Control	———	10	41	+ 7.3
Season of 1944				
Puratized**	1:10,000	20	38	−86.8
Puratized**	1:20,000	20	117	−76.9
Isothan Q15‡	1:5,000	20	307	−77.2
Isothan Q15‡	1:10,000	20	297	−56.9
Fermate	1:500	20	186	+ 2.2
Camden sulfur	1:250	20	198	+17.7
Control	———	20	335	+11.8

*Per cent increase (+) or decrease (−) in number of sporulating lesions.
**Puratized—phenyl mercuri triethanol ammonium lactate.
†Q4—lauryl pyridinium bromide.
‡Q15—lauryl isoquinolinium bromide.
§Concentration of fungicidal ingredient.

Liquid lime sulfur has been considered as unique among fungicides because of its socalled ability to "burn out" or "eradicate" Scab. Records extending over three spray seasons in a Rhode Island Station experimental orchard show that dilutions of 1 : 50 applied either during the daytime or nighttime cause a "burning" or necrosis of the foliage of from 24 to 62 per cent. Because of the severe foliage injury induced by lime sulfur and the consequent effect on growth and fruit production, it is but little used in spite of its eradication of the pathogen. The data in Table I indicate that certain of the new synthetic organic fungicides equal or surpass liquid lime sulfur in inactivating Scab lesions at dosages not injurious to foliage. The concentrations shown in Table I are based on approximate active toxicant. The technique used was to tag and then spray McIntosh leaves bearing active Scab lesions with the test fungicide, then four to six days later to note the increase or decrease in number, size, and sporulation. A lesion was considered as active when it continued to develop and sporulate. For the 1944 trial, twenty randomized infected leaves on ten trees were used for each fungicide. Active scab lesions cause leaf abscission resulting in defoliation, which decreases the food manufacturing ability of the tree.

Incompatability and instability with insecticides; such as oils, arsenicals, and nicotine, have proved to be the downfall of many new potentially effective organic fungicides. During the past two years of

experimentation, Isothan Q15 and Puratized N5D have not accentuated injury when used with or following these insecticides. In fact, lead arsenate caused less injury when used with these materials than it did alone or with some other fungicides, as shown by Table II. The surface active property of Isothan Q15 in particular has provided more perfect coverage of the plant organ, of itself and of lead arsenate combined with it, than older fungicides.

TABLE II—Reduction of Arsenical "Burn" on Apple Foliage

Material	Dilution	McIntosh		Baldwin	
		+ Lead	- Lead	+ Lead	- Lead
Puratized	1:15,000	0.14*	0.01	17.03	0.00
Isothan Q15	1:5,000	6.93	0 00	44.75	0.00
Control	———	35 00	0.00	75.00	0 00

*Per cent of foliage showing marginal and tip burn.

The data presented in Table II brings out the fact that six applications of lead arsenate during the season at the rate of three pounds per 100 gallons of spray mixture caused considerable injury when used alone. When used in conjunction with Puratized or Isothan Q15 the amount of injury was considerably less. Thus, these materials not only are compatible with lead arsenate but actually reduce the danger of arsenical burn. How this is brought about is not clear at present, but it appears that the improved uniformity of lead arsenate deposit may account in part for this result. Uniformity of coverage of toxicant permits control with lower dosages and increases the margin of safety against phytotoxicity.

Wetting agents have been added to sulfur and other particulate fungicides to permit their suspension in water, but little attention has been devoted to lowering the interfacial tension of the spray solution itself and hence its ability to cover the infection courts and to wet the pathogen. This factor has been considered in tailoring the molecular structure of the newest fungicides to meet disease control specifications. This provision for improving coverage also avoids the drying of arsenicals in heavy splotches of residue, which besides being unsightly and requiring removal expense, prevents even coloration of the fruit. The effect of Fermate Puratized N5D, and wettable Kolofog bentonite-sulfur combined with lead arsenate on the uniform deposition of residue can be seen in Fig. 1. Older fungicide applications have been regarded largely a matter of insurance against diseases, and like insurance there has been a premium; reckoned in terms of injury to the host plant. Dosages and schedules have been planned to minimize the phytotoxicity and yet to obtain practical control; which is often a compromise. The margin of safety of some newer organic fungicides is much greater than the older materials, while others have a narrow margin.

Since the chemicals are used to prevent injury from disease, their relative performance is of prime importance as seen in Table III. The commercial formulations differ in the amounts of toxicant and diluent

FIG. 1. McIntosh apples from trees sprayed with lead arsenate combined with Fermate, Puratized N5D, and wettable (Kolofog) bentonite sulfur (from left to right in pairs). The residue was wiped from the left-hand fruit of each pair to show the uneven coloration due to splotches of spray deposit. The Puratized sprayed fruit (center) had uniform coverage and even red color.

that they contain. Hence, they have been used on the basis of what is presumably their fungicidal ingredient. Examination of the data in Table 3 shows a high incidence of Apple Scab on trees not having fungicide applications. These "control" trees served as sources of abundant inoculum for other trees in the orchard and as a good yardstick for measuring the effectiveness of the fungicidal chemicals. Camden wettable paste sulfur controlled foliage Scab 64.5 per cent in 1943 and 93.3 per cent in 1944. Such variability in the degree of control from year to year should be considered in evaluating a fungi-

TABLE III—APPLE SCAB CONTROL OBTAINED ON MCINTOSH TREES WITH VARIOUS FUNGICIDES

Material	Dilution	Foliage		Fruit	
		Index	Control (Per Cent)	Index	Control (Per Cent)
		*Season of 1943**			
Puratized	1:5,000§	0.00†	100.0	0.0†	100.0
Isothan Q4	1:5,000	5.75	92.0	68.0	32.0
Fermate	1:500	27.5	63.1	66.7	33.3
Spergon (wettable)	1:400	53 25	28.7	85.8	14.2
Camden sulfur	1:250	26.0	64.5	36.4	63.6
Control	———	74.75	0.0	100 0	0.0
		*Season of 1944***			
Puratized	1:20,000§	0.031‡	99.7	0.50‡	96.6
Isothan Q15	1:5,000	0 666	94.0	1.64	88.8
Fermate	1:500	1 834	83.5	1.34	90.8
U. S. R. No. 604	1:800	0.020	99.8	——	——
Camden sulfur	1:250	0.739	93.3	1.64	88.8
Control	———	11 095	0.0	14.62	0.0

*Seven spray applications.
**Six spray applications.
†Per cent infected.
‡Average number of lesions per leaf or per fruit.
§Concentration of fungicidal ingredient.

cide. Wettable-Spergon proved to be unsatisfactory in 1943, but a new product of the U. S. Rubber Company No. 604 (1, 3 dichloronaphthaquinone) gave excellent control. At the concentration used, however, chlorotic mosaic-type symptoms developed in the foliage. Fermate was about equal to Camden sulfur in the 1943 orchard trials, but less effective in 1944. The two outstanding compounds, both years, were Isothan Q and Puratized which controlled Scab without foliage injury. Isothan Q was superior while Puratized sprays provided practically perfect suppression of Apple Scab as shown in Table I.

Some Trials With Methyl Bromide as a Fumigant for Rodents in Cold Storages

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The annual loss of apples in common and cold storages due to the activities of rats and mice is undoubtedly large. These losses often occur in storages of rodent-proof construction, since rats and particularly the mice, are carried into the storage with the fruit during the harvest season.

Strychnine treated oats, carefully placed about the storage, are recommended as a means of controlling rodents. Baiting methods, however, have not always been effective because growers often have failed to appreciate the important details of baiting, and under certain conditions it is difficult to expose the oats where the rodents will find them. Consequently, the fumigation of storages is worthy of consideration.

When initiating this study it was obvious that a fumigant possessing a low boiling point and good penetrating qualities was necessary if control was to be obtained. Methyl bromide has a boiling point of 40.1 degrees F. This material is so near its boiling point at cold storage temperatures that it evaporates and tends to diffuse very rapidly. It is also non-inflammable. The fact that it is odorless or practically so at many of its useful concentrations is an advantage because it cannot directly flavor the fruit. However, the lack of odor makes this material somewhat dangerous to humans who may not suspect its presence at lethal concentrations. Halide detectors are available and can be used as indicators of the presence of methyl bromide.

Sherrard (6) has shown that the minimum lethal dose for wild rats exposed to methyl bromide for four hours at 76 to 79 degrees F is ⅛ pound per 1,000 cubic feet. In dairy plants, at 70 degrees F or higher, Searles (5) has readily killed white laboratory rats in five hours, using approximately ⅕ pound per 1,000 cubic feet. Since the temperatures in cold storages are considerably lower than those employed by other investigators, a number of trials were conducted with rodents held at 32 degrees F, it being necessary to determine what concentration, if any, would give satisfactory control of rodents during a fumigation period of from 4 to 5 hours.

Methods and Materials

The white rats and mice employed were obtained from various laboratories at the University of Connecticut and the Connecticut Agricultural Experiment Station at New Haven. These rodents had been maintained on non-deficiency diets. The other rodents were collected in the field. At the end of each trial the animals were sexed. Weights were obtained, immediately after each given trial if the rodents were dead, or as soon as they had succumbed. The weight of the white mice ranged from 6.0 to 29.8 gms, the meadow mice from 22.7 to

47.0 gms, and the white rats from 48.7 to 618.1 gms. The pine mouse weighed 24.5 gms and the one wild rat weighed 40.5 gms. All tests were made at 32 degrees F. The rodents were placed at 32 degrees F at least 45 minutes prior to treatment with methyl bromide. Any animals which were not dead at the end of an experiment were placed at room temperature for further observation. No effort was made to seal any storage rooms where the tests were conducted.

Results

In an effort to determine the rate at which various dosages of methyl bromide kill, adult white rats were placed in separate 5-gallon glass containers and subjected to various concentrations of fumigant. Each treatment was repeated three times. The time required to kill the rats was recorded in each instance. The results are given in Table I.

TABLE I—The Effect of Various Concentrations of Methyl Bromide on the Survival Time of White Rats at 32 Degrees F

Treatment (Pounds per 1,000 Cubic Feet)	Sex	Average time to kill (Minutes)
0.50	Female	196
0.50	Male	212
1.00	Female	146
1.00	Male	160
2.00	Female	110
2.00	Male	135
4 00	Female	76
Control	Female	Not dead after 4 hours at 32 degrees F
Control	Male	Not dead after 4 hours at 32 degrees F

It can be seen that the mortality rate increases as the concentration of methyl bromide is raised. However, the rate of kill is not directly proportional to the concentration of fumigant. Male rats were generally more resistant to the effects of methyl bromide than were the females.

Since all the concentrations employed in the previous experiment killed the rats in less than 4 hours, it appeared that ½ pound or less would be satisfactory. In an effort to determine the effectiveness of this fumigant under circumstances similar to those found in commercial cold storages, some tests were made in a room with the capacity of 900 cubic feet. This room was filled with empty apple crates since apples were unavailable for the purpose. The rodents were placed in cages and distributed systematically about the room so that the effectiveness of the fumigant throughout the room would be known. In all but trial number 3, the air was circulated by a large fan for 5 minutes. After 4 hours the animals were removed and the data presented in Table II recorded.

The data show that none of the animals survived once they were subjected to the vapors of methyl bromide. In general, it was the heavier individuals which were alive after the 4 hour treatment of ¼ pound of fumigant per 1,000 cubic feet, but they never recovered from the effects of methyl bromide. The white rats appeared to be paralyzed

in their extremities and were unable to move when placed at room temperature. When food was placed in front of these rats they showed no desire to eat. Within 40 hours following treatment all rats were dead.

Where no circulation was provided, in trial number 3, the per cent mortality for white rats immediately following the 4-hour treatment was much lower than where some air movement was supplied. Undoubtedly some air circulation is necessary to prevent any methyl bromide stratification and insure the most rapid rate of kill throughout a fumigation chamber.

A trial in a commercial storage with a capacity of 30,000 cubic feet was conducted. The room held approximately 6,500 empty crates but no fruit. The room was cooled to 32 degrees F and the air circulated by a diffuser. Since there had not been a complete kill during a 4-hour exposure to ¼ pound of methyl bromide per 1,000 cubic feet, a 5-hour treatment period using ¼ pound of methyl bromide was decided upon. The rodents were put in cages and distributed amongst the crates and throughout the room.

The results presented in Table III show that no rodent survived this 5-hour treatment.

Before entering this room the two ports on the walls and the doors were opened while the diffuser was operated to "air-out" the room. After 40 minutes no evidence of methyl bromide could be detected by the use of a halide detector.

Discussion

Although methyl bromide appears to be a very effective fumigant for rodents in cold storages, further studies must be made to determine

TABLE II—The Effectiveness of Methyl Bromide in Killing Rodents in a Small Storage Room at 32 Degrees F

Trial	Treatment (Pounds per 1,000 Cubic Feet)	Species	Number of Rodents	Age	Per Cent Mortality	
					After 4 Hours	After 2 Days
1	1 pound for 4 hours + air circulation	White mice	6	Juvenile	100.0	100.0
		White mice	3	Adult	100.0	100.0
		Meadow mice	4	Adult	100.0	100.0
		Pine mice	1	Adult	100.0	100.0
		White rats	6	Juvenile	100.0	100.0
		White rats	6	Adult	100.0	100.0
2	¼ pound for 4 hours + air circulation	White mice	4	Juvenile	100.0	100.0
		White mice	5	Adult	100.0	100.0
		Meadow mice	3	Adult	100.0	100.0
		White rats	5	Juvenile	100.0	100.0
		White rats	9	Adult	55.6	100.0
3	¼ pound for 4 hours no air circulation	White mice	3	Adult	100.0	100.0
		Meadow mice	2	Adult	50.0	100.0
		Wild rat	1	Juvenile	100.0	100.0
		White rats	3	Juvenile	0.0	100.0
		White rats	5	Adult	0.0	100.0
4	Control	White mice	3	Juvenile	0.0	0.0
		White mice	4	Adult	0.0	0.0
		Meadow mice	2	Adult	0.0	0.0
		White rats	2	Juvenile	0.0	0.0
		White rats	6	Adult	0.0	0.0

the influence of this material on the fruit. One of the questions which might be raised is whether apples will absorb enough methyl bromide to be harmful to humans. Dudley and Neal (1) found that apples absorbed 0.30 mg of bromine per 100 gms of fresh material when subjected to a concentration of 2 pounds of methyl bromide per 1,000 cubic feet for 2 hours at room temperature. Since rats fed on a diet containing from 5.55 to 9.36 mg per 100 gms of food for 52 weeks were unaffected, it seems extremely unlikely that anyone would be poisoned by eating apples treated with methyl bromide.

TABLE III—THE PER CENT MORTALITY OF RODENTS PLACED IN A COMMERCIAL COLD STORAGE AND SUBJECTED TO VAPORS OF METHYL BROMIDE AT 32 DEGREES F

Treatment (Pounds per 1,000 Cubic Feet)	Species	Number of Rodents	Per Cent Mortality After 5 Hours Treatment
¼ pound for 5 hours	White mice	16 adult males	100.0
	White mice	19 adult females	100.0
	White rats	12 adult males	100.0
	White rats	6 adult females	100.0

However, the influence of methyl bromide on the rate of ripening of immature apples must be known. To the authors' knowledge no studies of this type have been conducted with apples although there are some reports dealing with other fruits. Knott and Claypool (3) found that the rate of respiration of tomatoes in the "mature green" stage was markedly increased for the first few days after treatment with methyl bromide. This accelerating influence did not persist, however, and the rate dropped below that of the controls after 3 or 4 days. No such influence was noted when tomatoes were in the "pink" stage. In their ripening tests, they found that at temperatures below 80 degrees F methyl bromide delayed the rate of development of red color in tomatoes. At 80 degrees F, however, the rate of ripening was hastened slightly. Jones (2) reports that a treatment of 2 pounds of methyl bromide per 1,000 cubic feet for 2 hours at room temperature delayed the ripening of papaya 3 to 4 days but increased the amount of decay. The rate of ripening of tomatoes so treated was similarly delayed but no increase in rotting was apparent. Mackie and Carter (4) found no difference in the firmness of pears treated at room temperature with 2 pounds of methyl bromide per 1,000 cubic feet for 2 hours and that of similar untreated fruit after they had been stored for 3 months at 35 degrees F.

Although it appears that methyl bromide is considered sufficiently "safe" for use on many fruits, complete details are not available as to its influence on stored apples. Consequently, studies are being made to determine the response of apples, at various stages of maturity, to treatments with methyl bromide.

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Injury to Williams Apples Resulting From Fumigation with Methyl Bromide

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ACCORDING to regulations of the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, apples shipped from the Japanese beetle quarantine area into non-infested areas must be fumigated or otherwise certified that they are free from Japanese beetles. During the 1944 season, 36 cars of Williams apples were fumigated with methyl bromide and shipped from Delaware. The apples from these cars were rejected on midwestern markets because of a condition described by inspectors as "internal brown discoloration" and "surface scald." Non-fumigated Williams apples which were shipped under like conditions to similar destinations arrived in satisfactory condition. Other varieties of apples (Starr, Yellow Transparent, and Wealthy) shipped under fumigation were not affected. The evidence from these commercially shipped cars seem to indicate that methyl bromide may cause injury to some varieties of apples and not to others.

REVIEW OF LITERATURE

Phillips, Monro and Allen (1), working with McIntosh apples, found that methyl bromide caused both internal and external injury. Most of the injury, however, was internal. The injury increased when the apples were removed from 39 degrees F storage to 60 degrees F storage for 1 week. In some cases injury developed after removal from 39 degrees F storage when there was no apparent injury at the time of removal. Immature and overripe fruit showed greater injury resulting from methyl bromide fumigation than mature fruit. Storage of fruit for 4 to 6 weeks before fumigation resulted in a reduction or elimination of the injury.

Phillips and Monro (2) reported that McIntosh and Jonathan apples showed injury when fumigated with methyl bromide while Delicious, Stark, Ben Davis, Rhode Island Greening, and Baldwin showed no injury. Chapman (3) also observed injury to McIntosh apples when fumigated with various concentrations of methyl bromide.

GENERAL OBSERVATIONS

Fumigation of iced cars, apparently, has been conducted on a large scale for the first time during the 1944 season. Forty-four cars of apples shipped from Delaware were fumigated at one station. The fumigation procedure briefly is as follows: A blower with at least 600 c. f. m. delivery is placed inside one bunker of the car and the air circulated for 10 minutes. Two temperature readings, one for the bottom of the car and the other for the top of the load are recorded. An average of these temperatures determines the dosage. The charge of methyl bromide is injected into the car by means of an applicator with

a copper tube leading down in front of the blower. The blower is permitted to run during the injection and for 5 minutes after all the methyl bromide has been injected. The car is then tightly closed for 2 hours. At the end of this period, one door and two hatches are opened for 20 minutes to permit the bromide to drift out. The car is then ready for shipment.

The cars of apples fumigated in Delaware were under iced conditions from 16 to 24 hours prior to fumigation. A car of Williams that had been iced for 22 to 23 hours was observed for temperature conditions. The air temperature at the floor of this car was 48 degrees F and the temperature on top of the load was 79 degrees F. The average car temperature which would have been used to determine the dosage was 63 degrees F. The fruit and basket temperatures of the two upper layers were above 75 degrees F. This indicates that the fruit in the two upper layers was 10 to 15 degrees F higher than the average car temperatures. Temperature records at the fumigation station showed a like stratification of air temperatures inside similar cars.

The inspection reports from the destination show that the degree of internal breakdown varied from near zero to 100 per cent. Also several cases of a stratification of injury or breakdown were reported. This stratification of injury was in correlation with the stratification of air temperatures.

Experimental Procedure

In order to observe the effects of methyl bromide fumigation upon certain varieties of fruit, an iced car was placed on a siding at Bridgeville, Delaware. Representatives of the Pennsylvania Railroad, who had been applying the fumigation commercially, were obtained to fumigate this car. Starr, Wealthy and Williams apples and Golden Jubilee peaches were treated. The following treatments, two bushels each for each variety, were selected on the basis of the general observations of temperature stratification:

1. Fruit left in the car overnight, removed for the fumigation period and replaced in the car after fumigation.
2. Fruit placed in the car overnight and fumigated the next day. (Temperature inside of basket when fumigated, 59 degrees F).
3. Fruit left in packing shed overnight, placed in car just prior to fumigation. (Temperature inside of basket when fumigated, 79 degrees F).

The air temperatures of the car at the time of fumigation averaged 53 degrees F. This required an eight-pound dosage of methyl bromide according to the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, dosage chart. The car, after fumigation, was left standing with fruit in place for 8 days. At 2-day intervals 20 fruits were taken at random from each bushel for observations. After 8 days all fruit was removed and the Williams retained at room temperature for 24 hours for further observations on degree of injury.

During the experimental period, the car was re-iced as needed.

On July 21, the day of fumigation, 4,000 pounds of ice was added to the bunkers and on July 25, 6,600 pounds of ice was added. At no time during the period of observation did the car temperature exceed 50 degrees F.

Observations on Williams Apples

In Table I is presented the total number of fruit observed, number of fruit showing external injury, and number of fruit showing internal injury at 2-day intervals after fumigation.

The data presented in Table I, show that methyl bromide fumigation definitely caused injury to Williams apples. Nine days after fumigation, external and internal injury was 86 and 98 per cent, respectively. Fruits that were not fumigated showed no injury. The external injury developed within 2 days after fumigation while the initial internal injury required more time. The advanced stage of internal injury was not evident until 6 days after fumigation. At this time it was apparent that the initial injury had progressed in some cases to the advanced stage. Also, there was greater external and initial internal injury with higher fruit temperatures when fumigated.

TABLE I—Progressive Development of Methyl Bromide Injury to Williams Apples

Treatment No.	No. Fruits Observed	Surface Injury		Internal Injury					
				Initial		Advanced		Total	
		No. Fruits	Per Cent	No. Fruits	Per Cent	No. Fruits	Per Cent	No. Fruits	Per Cent
Jul 23—2 Days After Fumigation									
1*	40	0	0.0	0	0.0	0	0.0	0	0.0
2**	40	14	35.0	0	0.0	0	0.0	0	0.0
3†	40	33	82.5	0	0.0	0	0.0	0	0.0
Jul 25—4 Days After Fumigation									
1	40	0	0.0	0	0.0	0	0.0	0	0.0
2	40	19	47.5	29	72.5	1	2.5	30	75.0
3	40	34	85.0	37	92.5	1	2.5	38	95.0
Jul 27—6 Days After Fumigation									
1	40	0	0.0	0	0.0	0	0.0	0	0.0
2	40	16	40.0	29	72.5	8	20.0	37	92.5
3	40	33	82.5	30	75.0	4	10.0	34	85.0
Jul 29—8 Days After Fumigation									
1	40	0	0.0	0	0.0	0	0.0	0	0.0
2	40	17	42.5	21	52.5	12	30.0	33	82.5
3	40	30	75.0	27	67.5	10	25.0	37	92.5
Jul 30—24 Hours in Common Storage. Removed from Refrigerated Car Jul 29									
1	100	0	0.0	0	0.0	0	0.0	0	0.0
2	100	35	35.0	59	59.0	34	34.0	93	93.0
3	100	86	86.0	56	56.0	42	42.0	98	98.0

*Not fumigated.
**Temperature inside of basket when fumigated, 59 degrees F.
†Temperature inside of basket when fumigated, 79 degrees F.

Observations on Other Varieties

Starr and Wealthy apples and Golden Jubilee peaches showed no injury resulting from fumigation with methyl bromide at any observation.

Description of Injury

Surface Injury or "Scald":—Light brown spots occurring at any point on fruit. Areas slightly depressed and brown tissue extending slightly below the skin. Discolored areas varying in size from 1/8 to 3/4 inch in diameter. Number of discolored areas per fruit vary from few to many and often coalesced and covered the entire fruit. (Fig. 1)

FIG. 1. Surface injury to Williams apples resulting from methyl bromide fumigation.

Initial Internal Injury:—Outer edge of carpel wall brown in appearance. Inner surface of carpel wall often brown over entire surface. Extreme center of carpel wall often brown. Some slight invasion of flesh near outer edges of carpel wall. Stem darkened and shriveled with brown streaks at base extending to the edges of the carpel wall. (Fig. 2)

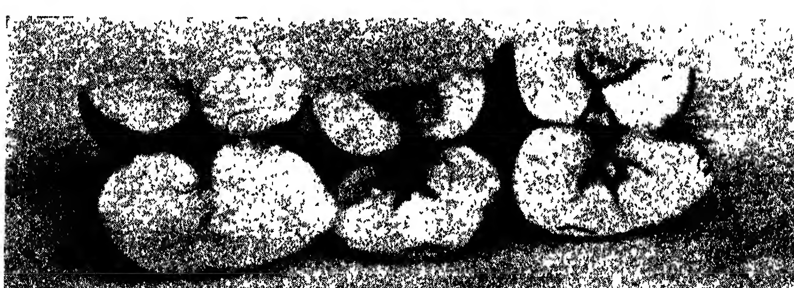

FIG. 2. Initial internal injury to Williams apples resulting from methyl bromide fumigation. Fruit on the left is a normal non-fumigated apple.

Advanced Internal Injury:—Two types of internal brown discoloration were observed. The most prevalent type was found to develop in the flesh near outer edge of carpel wall. The invaded area gradually extended to surround core and inner cortex with a clear line of

demarcation. Some fruits entirely brown. The other type appeared to develop uniformly from the skin inward and often invaded the entire fruit. (Fig. 3)

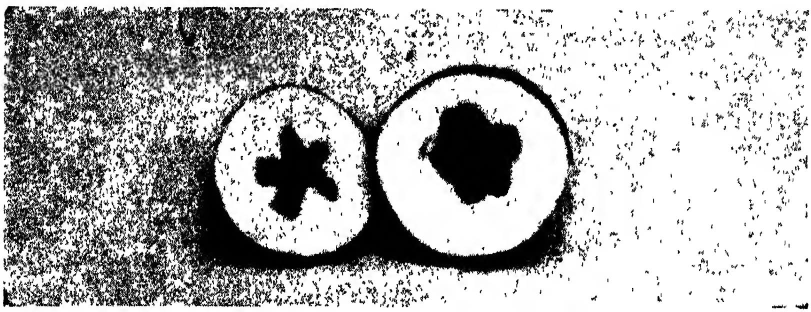

Fig. 3.—Advance internal injury to Williams apples resulting from methyl bromide fumigation. The fruit on the right shows injury near the surface in addition to injury around the core.

Summary

Williams apples were severely injured by methyl bromide fumigation when it was used at the dosage recommended for Japanese beetle control. Higher fruit temperature at the time of fumigation caused greater surface injury or "scald." Initial internal breakdown was present in a larger percentage of the fruits when the fruit temperature was higher. Advanced internal injury seemed to be independent of fruit temperature at the time of fumigation. Advanced internal injury tended to increase rapidly after removal from the car with the higher fruit temperatures at the time of fumigation causing the most rapid development. Starr and Wealthy apples and Golden Jubilee peaches were not injured by fumigation with methyl bromide when used at the recommended dosage.

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Methyl Bromide as a Fumigant for Rats and Mice in Apple Cold Storages[1]

By ROBERT M. BORG, *U. S. Department of the Interior, Fish and Wildlife Service* and LAWRENCE SOUTHWICK, *Massachusetts State College, Amherst, Mass.*

IN recent years, rodents (rats and mice) have become pests of considerable economic importance in fruit and vegetable storages in spite of the use of present control measures — poisoning, trapping, and proofing. A search of the literature revealed the possibility of methyl bromide as an effective fumigant to use in fruit storages. Methyl bromide (CH_3Br) is a colorless, practically odorless (resembles that of chloroform), volatile liquid, with a specific gravity of 1.732 at 0 degrees C and a boiling point of 40.1 degrees F. At ordinary temperatures, it is a gas approximately 3.3 times as heavy as air. It is soluble in most common organic solvents but only slightly so in water. It is usually noninflammable. Since it has a low boiling point, it tends to evaporate and diffuse very rapidly. And since it is practically odorless and has a low water solubility, the chance that low concentrations would leave a residual odor or taste on fruit in cold storage would seem to be practically negligible.

PROCEDURE

A small room (734.4 cubic feet) in the apple storage at Massachusetts State College was used. This room is separated from adjacent chambers by heavily insulated walls and contains brine coils for refrigeration. There is one small window near the ceiling in the back wall. This was replaced with heavy brown paper firmly sealed to prevent the escape of gas. An electric fan was set up on the window just inside the paper seal. When it was desired to vent the room of the methyl bromide gas, the paper seal was broken from the outside and the fan was turned on. Another fan near the floor helped to air the room quickly. At the end of 10 minutes venting, no evidence of methyl bromide could be detected by the use of a halide detector.

Only enough boxes were stacked in the room to make it possible to expose the rodents at varying heights in cages containing litter and bedding, used as nests. All animals used in the tests were placed in the room about 1 hour before treatment with methyl bromide. Several varieties of apples were placed in the room for each separate test so that any injury to the exposed fruit might be checked. Using a gas mask, the senior author in each test liberated the desired quantity of the gas in the room. A circulating fan on the floor was turned on at low speed and run continuously to prevent possible stratification of the gas and to provide the most rapid rate of kill.

[1]Contribution No. 544 from the Massachusetts Agricultural Experiment Station.

Results

Test No. 1 (May, 1944):—Since experiments by others (1, 3, 8, 9, 10, 11) revealed that various dosages of methyl bromide at different temperatures were lethal to rodents (mice and rats) and other animals, it was decided to use certain concentrations at 34 degrees F (a common apple storage temperature) and at various exposure periods to determine not only the effect of the fumigant on warm-blooded animals but also possible injuries to exposed fruit. The test in Table I was run on May 4, 1944, when the fruit was mature and respiring relatively slowly.

TABLE I—Effect on Animals of Methyl Bromide Used at the Rate of 0.25 Pounds per 1000 Cubic Feet of Storage Space

Species	Sex	Age	Weight (Gms)	Hours of Exposure Resulting in Death
House Mouse	Female	Adult	13 0	3
House Mouse	Male	Adult	15.6	3
House Mouse	Female	Adult	20.0	3
House Mouse	Female	Adult	17.6	3
White Rat	Male	Adult	295 7	4
White Rat	Male	Adult	286.7	4
White Rat	Female	Immature	112.0	3
White Rat	Female	Immature	91.0	3
Rabbit	Female	7 weeks	2 lbs. 11 oz.	5
Rabbit	Male	7 weeks	2 lbs. 14 oz.	5*

* Paralyzed and died 1 day later.

With the four varieties of apples used, namely, McIntosh, Rhode Island Greening, Cortland, and Baldwin, it is significant that immediately after fumigation and at the end of one month no taste or odor was detected and no injuries to the apples occurred when held at temperatures of 33 to 36 degrees F.

Test No. 2 (October, 1944):—On October 9–10, 1944, a series of tests were made with various animals and freshly picked fruit. Table II gives the results.

The data show that none of the animals survived once they were exposed to methyl bromide. In all tests, generally, the heavier individuals required a longer exposure period before death ensued. This was particularly true (Table II) where ⅛ pound of methyl bromide was used per 1000 cubic feet of storage space. Further, the rate of killing of the various animals increased in proportion to the concentration of methyl bromide used. Any animals which were not dead at the end of the tests were placed at room temperature for further observation. When food was placed in front of these animals, they showed no desire to eat. All control animals kept at 34 degrees F and fed survived.

Four varieties of apples were used in this test, namely, McIntosh, Cortland, Delicious, and Baldwin. These were held after fumigation at a temperature of 33 to 36 degrees F. A slight chloroform odor was detected on all varieties of fruit subjected to various dosages immediately after fumigation. At the end of 24 hours, however, no odor was noticeable. There was no apparent taste either immediately after fumigation or two weeks later. And no injuries occurred to the fruit.

TABLE II—EFFECT ON ANIMALS OF METHYL BROMIDE USED AT VARIOUS DOSAGES AS SHOWN BELOW

Species	Sex	Age	Weight (Gms)	Effect on Animals
0.125 Pounds per 1,000 Cubic Feet of Storage Space for 6 Hours				
White Rat	Female	Mature	182.0	Paralyzed, died in less than 12 hours
White Rat	Female	Mature	162 8	Death
White Rat	Male	Immature	75.0	Death
White Rat	Male	Immature	71.0	Death
White Rat	Female	Mature	164.1	Paralyzed, died in less than 12 hours
White Rat	Female	Mature	171.0	Paralyzed, died in less than 12 hours
White Rat	Female	Mature	157.3	Paralyzed, died in less than 12 hours
White Rat	Female	Mature	167.0	Paralyzed, died in less than 12 hours
White Rat	Male	Mature	193.4	Paralyzed, died in less than 12 hours
White Rat	Female	Mature	193.4	Paralyzed, died in less than 12 hours
House Mouse	Male	Mature	23.7	Paralyzed, died in less than 12 hours
Guinea Pig	Male	Mature	515.4	Paralyzed, died in less than 12 hours
Guinea Pig	Male	Mature	518.3	Paralyzed, died in 24 hours
0.25 Pounds per 1,000 Cubic Feet of Storage Space for 4 Hours				
House Mouse	Male	Adult	25.0	Death
White Rat	Male	Adult	215.5	Death
White Rat	Female	Adult	199.5	Death
Meadow Mouse	Male	Adult	40.0	Death
Meadow Mouse	Male	Adult	27 5	Death
Meadow Mouse	Female	Juvenile	17.5	Death
Meadow Mouse	Female	Adult	29 5	Death
Meadow Mouse	Male	Juvenile	14.0	Death
0 50 Pounds per 1,000 Cubic Feet of Storage Space for 2 Hours				
Wild Rat	Female	Mature	190.5	Death
Wild Rat	Male	Mature	376 0	Paralyzed, died in 4 hours
White Rat	Female	Immature	86.0	Death
White Rat	Female	Immature	85.0	Paralyzed, died in 4 hours
House Mouse	Male	Mature	25 2	Death
House Mouse	Male	Mature	24 0	Death
Meadow Mouse	Male	Mature	28 0	Paralyzed, died in 5 hours
Meadow Mouse	Female	Mature	15.5	Death
1.0 Pounds per 1,000 Cubic Feet of Storage Space for 1 Hour				
White Rat	Female	Mature	204.0	Paralyzed, died in 1 hour
White Rat	Female	Mature	180.8	Paralyzed, died in 1 hour
White Rat	Female	Mature	207.5	Paralyzed, died in 3 hours
White Rat	Male	Mature	180.7	Paralyzed, died in 3 hours
Meadow Mouse	Male	Mature	27.3	Paralyzed, died in 3 hours
Meadow Mouse	Female	Mature	24 7	Paralyzed, died in 3 hours
Meadow Mouse	Female	Mature	17 7	Paralyzed, died in 3 hours
House Mouse	Male	Mature	21 3	Death
House Mouse	Male	Mature	24.7	Death
House Mouse	Female	Mature	25.6	Death

DISCUSSION

There can be little doubt that relatively small dosages of methyl bromide will kill rats and mice under apple storage temperatures, as brought out by these tests, and at other temperatures tested by various workers. But the effect of the vapors of methyl bromide on apples at various stages of maturity and at different concentrations in cold storage has not been checked to the authors' knowledge. Mackie and Carter (7) found that fresh pears treated with two pounds of methyl bromide per 1000 cubic feet for 2 hours at approximately room

temperature contained a trace of bromine residue 24 hours after treatment and no residue at the end of 48 hours. They also found no apparent difference between the check and the treated pears fumigated with the same dosage for the same exposure period on August 18 and placed in cold storage at 35 degrees F until November 11 — 85 days later. Jones (4) found that treatment with two pounds of methyl bromide per 1000 cubic feet for 2 hours at room temperature delayed the ripening of papayas and tomatoes 3 to 4 days and increased the rotting of papayas. Knott and Claypool (5) found that high concentrations, i. e., 2–4 pounds per 1000 cubic feet were injurious to ripening tomatoes. On the other hand, Mackie and Carter (6) reported that early potatoes, bunch beets, cabbage, green beans, egg plant, radish, turnip, and other plant materials were found in excellent condition at the end of 8 days (potatoes 5 days) when held at 45 degrees F and after they had been fumigated at 76 degrees F for 90 minutes (potatoes 2 hours) in a concentration of 2.5 pounds (potatoes 4.25 pounds) of methyl bromide per 1000 cubic feet.

It thus appears from tests already run that dosages of more than one pound per 1000 cubic feet may sometimes be injurious at relatively high temperatures. However, in most of the work that has come to the knowledge of the authors, no harmful effects were noted. Furthermore, there seems to be a relationship between possible injury from a particular dosage and the temperature. The lower the temperature the less the likelihood of injury. Thus, apples at cold storage temperatures probably can withstand a relatively high dosage. At least, there was no observable injury at the highest dosage used by the authors — one pound for one hour.

In addition to the injuries which might occur on the material fumigated, there is the possibility of danger to humans consuming the food material. Stewart and Mackie (11) report that rats fed for 6 months on a specially prepared diet and dried fruits thoroughly fumigated with methyl bromide gained weight and remained active and alert. Dudley and Neal (2) found that rats which were fed a diet containing from 5.5 to 9.3 milligrams of methyl bromide per 100 grams of apple showed no ill effects at the end of 52 weeks. These tests show that the food material treated with methyl bromide was not rendered toxic by absorption or adsorption of the fumigant.

The exact form in which bromine residue exists on fruits and vegetables is not known. But Mackie and Carter (7) state that it is the consensus among chemists that it occurs as an inorganic bromide which would be harmless in the amount present.

In fumigating storages with methyl bromide the following should be strictly followed for best results. 1. The storage should be sealed as tightly as possible. 2. Adequate appliances should be arranged to expose the exact amount of fumigant. 3. Proper venting facilities should be set up that can be put into effect immediately after treatment without entering the storage as a quick and complete change of air is desirable. 4. The use of a halide detector is recommended to determine the presence of methyl bromide after venting.

Since methyl bromide is injurious to all forms of animal life, proper

caution should be observed when handling it. It is, therefore, inadvisable for anyone except experienced technical personnel to attempt to handle liquid methyl bromide without first having attended a demonstration in its use.

Conclusion

Fumigation tests with methyl bromide in an apple cold storage room showed that this material is very effective in killing mice and rats without causing any observable injury to or effect on the fruit. It would seem that this method of exterminating destructive rodents in apple storages has considerable merit. A good dosage seems to be ¼ pound per 1000 cubic feet of storage space for a 4-hour period or possibly ½ pound for a 2-hour period. It should be remembered that in a room well filled with fruit, the "space" may be reduced as much as one-half, thus reducing the actual weight of gas required for a standard dosage. Caution must be observed in using methyl bromide as it is injurious to man as well as other animals.

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A Method of Measuring the Degree of Kernel Development of Samples of Pecans

By F. N. Dodge, *U. S. Department of Agriculture, Shreveport, La.*[1]

In studies of pecan production problems it is generally desirable to obtain data on the amount and quality of kernel development made by the pecan nuts of different varieties, or of any given variety grown under different cultural treatments. In evaluating results of treatments the data on kernel development is of equal value with those on yield and size, as the kernels are the edible part of the nut.

A number of criteria of kernel development have been used by workers in pecan production problems. Crane and Hardy (1) cracked the pecans and estimated the degree of kernel development. Sitton (3) at first used the ratio of kernel weight to weight of shell, but found this method unsatisfactory. He then used the specific gravity of the nut. Romberg, Hamilton, and Smith (2) also found specific gravity to be a good measure of the kernel development of the pecan nut and that the weight of kernel per cc. of nut volume, or the degree of filling, was very closely correlated with the specific gravity of the nut in all cases. Sitton (4) later classified pecans according to their specific gravity by .01 intervals and showed by sectioning the nuts that kernel development increased with an increase in the specific gravity of the pecan nut. He reported that the specific gravity of the pecan nut apparently furnishes a measure of all the factors affecting filling, whether filling is complete or incomplete. It is, therefore, apparent that in experimental work the specific gravity of the pecan nut may be used as a measure of its degree of filling, or kernel development. In like manner, since the individual nuts make up the sample, the specific gravity of the sample should be a measure of its composite degree of kernel development.

Data Necessary in the Study of Pecan Filling

In obtaining data on the kernel development of pecan nuts grown in experimental plots it is hardly possible to examine all the nuts grown on all the trees in the experiment. This difficulty is overcome by taking several representative replicated samples of nuts from each plot. If the principles of sampling technic are observed it is possible to obtain data from these samples after they have been air dried that can be analyzed statistically and determination made of the mathematical significance of differences due to cultural treatment, variety or other factors.

The information usually desired in a study of the physical qualities of pecan nuts is their size and degree of kernel development. This information can be quickly obtained by using air-dry samples of seven

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[1]The author is indebted to Dr. B. G. Sitton for the design of the hydrometer shown in Fig. 1, and for the design and construction of the balance shown in Fig. 2.

hundred to nine hundred grams each. The samples should be replicated, and in obtaining the data one series of samples constituting a replication should be studied at a time, and finished before another is started. This will avoid the possibility of obtaining a bias in the data resulting from changes in moisture content of the nuts while the work is being done, or of obtaining a bias because of a change in the judgment of the worker during the period the study is being made. The number of nuts in the sample, the weight of the sample, and the water displacement of the sample are found. From these data the mean weight per nut, the mean specific gravity of the nuts, and the mean displacement per nut may be calculated. The number of nuts per pound may be determined, if desired, from the data on mean weight of the nuts. By a method to be described, the individual nuts of the sample can be separated into several specific gravity classes. Data from this classification will show the fractions of the sample of nuts which have well developed, moderately developed, or poorly developed kernels, respectively.

Apparatus

In determining the specific gravity of individual pecans the buoyancy method described by Waugh (5) has been found to be both rapid and sufficiently accurate for this work. Fig. 1 shows a hydrometer that has proven more satisfactory than the one described by Waugh. Fig. 2 shows a balance useful for weighing individual nuts.

This balance is of home construction. The scale is graduated in grams, to 0.1 gram. Weighings can be rapidly made with the same degree of accuracy as with a torsion balance, and with considerable saving of time. If very many weighings are to be made, one of this type would be helpful. By using this balance together with the hydrometer shown in Fig. 1 and the nomogram published by Waugh (5) the approximate specific gravity of fifty pecans were determined by one worker in an hour. It is necessary that distilled water be used at the temperature at which the hydrometer was calibrated, otherwise errors will result.

To determine the buoyancy of samples composed of many nuts, the hydrometer shown in Fig. 2 was used. The similarity in design of this hydrometer to the one shown in Fig. 1 can be readily seen. The hydrometer shown in Fig. 2 was made by a local sheet-metal worker. A 500 ml. graduated cylinder was used for the stem of the hydrometer. The lower wire part holds the nut sample and has a capacity of about 2 liters. A sheet-metal cuff at the base holds pieces of lead and serves as a sinker, causing the hydrometer to float perpendicularly. In calibrating this hydrometer several samples of approximately 400 grams each of poorly filled pecans were shellacked to keep them from absorbing water. The buoyancy of these samples was obtained by weighing each sample on a torsion balance, and then determining the total displacement of the sample by measuring the amount of water it displaced in a calibrated 2-liter erlenmeyer flask. Buoyancy is taken to be the difference between the total water displacement of the sample

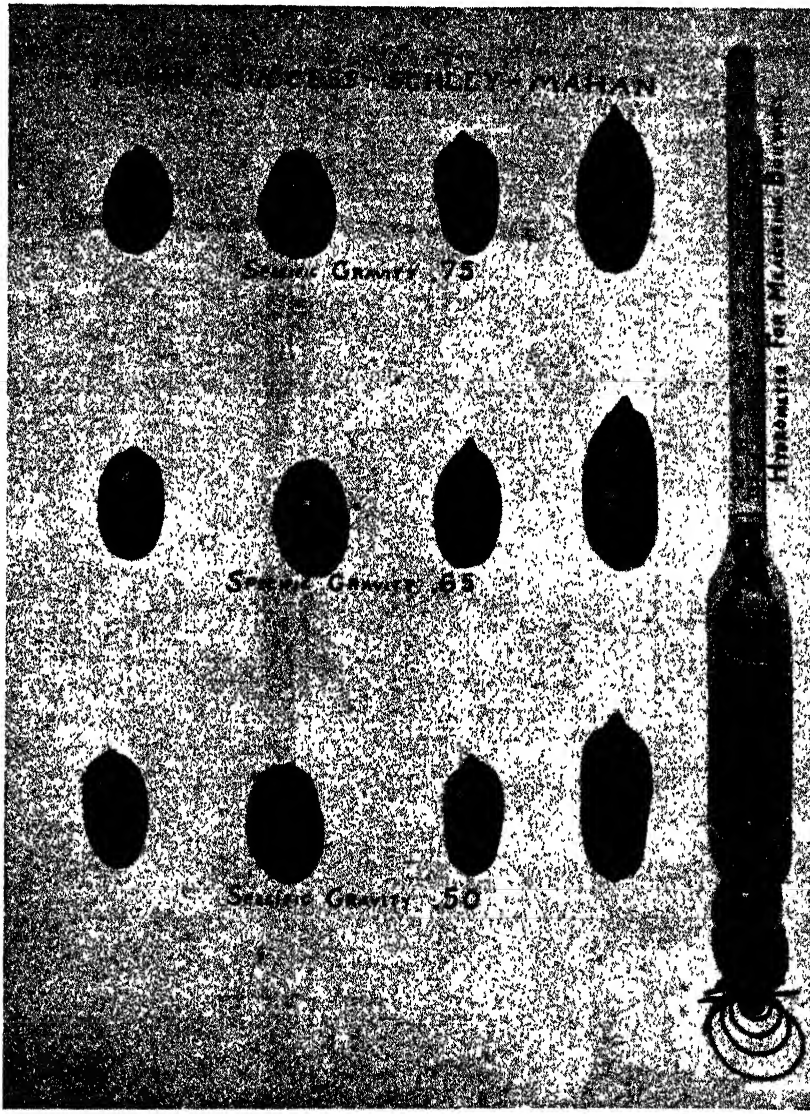

FIG. 1. Hydrometer used for determining the buoyancy of individual pecan nuts, and pecan nuts of four varieties. Reading from left to right these are: Moore, Success, Schley, Mahan. Nuts in the top row have a specific gravity of .75; in the middle row, a specific gravity of .65; and in the bottom row a specific gravity of .50. The black line on each nut marks the line of contact of the surface of the nut with the liquid in which it floated. The light area is the area of the nut that was above the surface of the liquid. The nuts having a specific gravity of .75 and .65 were floated in 95 per cent ethyl alcohol at 20 degrees C, and the .50 specific gravity nuts were floated in distilled water at 20 degrees C.

and the displacement by the immersed parts of the nuts as they float. This latter factor is equivalent to the weight of the nuts. Hence the formula used in determining the buoyancy of the sample is: Total Displacement in ml. (= gm.) minus Weight of Sample in grams equals Buoyancy of Sample in grams.

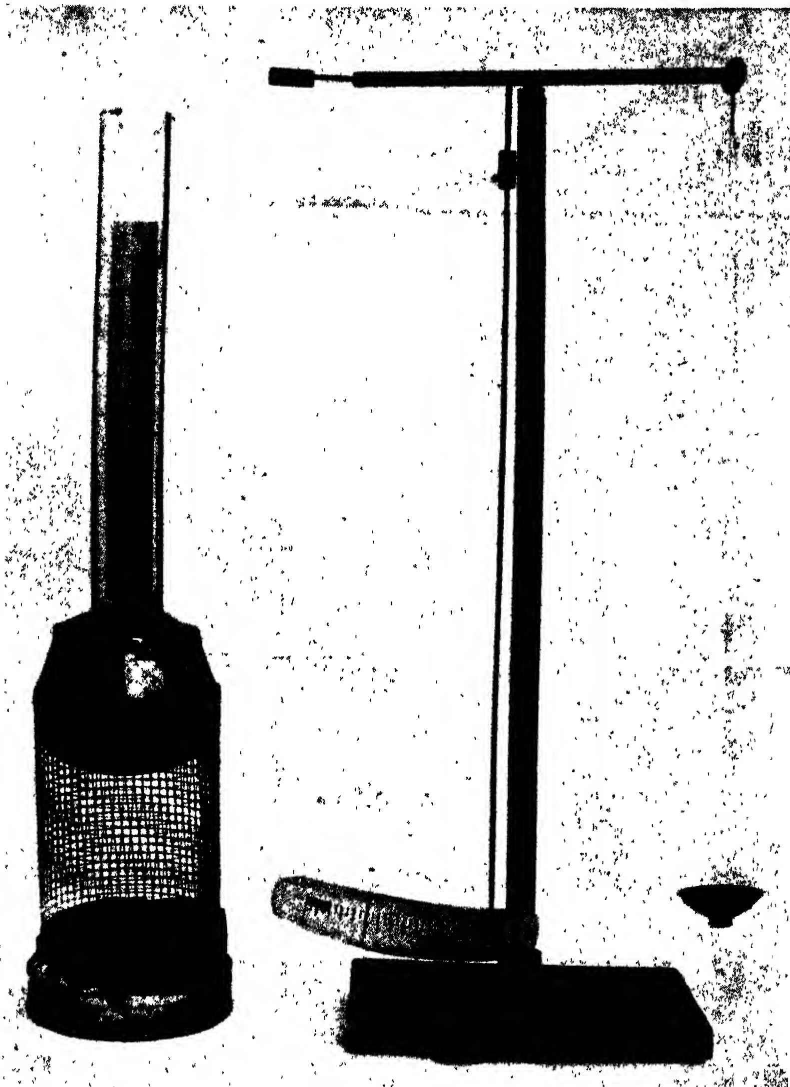

FIG. 2. A balance for weighing individual pecan nuts without the use of weights, and a hydrometer for measuring the buoyancy of samples of pecans.

After the buoyancies of the several samples had been determined each one was placed in the hydrometer and floated in distilled water at 20 degrees C. The reading of the edge of the meniscus of the water on the graduated cylinder was recorded for each sample together with the buoyancy of the sample as previously determined gravimetrically, and thus the relationship of the cylinder graduations and the corresponding buoyancies was determined. From this relationship a new set of graduations was made on heavy white paper and glued to the inside of the cylinder. These new graduations give a direct reading of the buoyancy of the sample in grams. The shellacked pecans were used again to check the new scale of graduations for buoyancy expressed in grams, using the same procedure as in calibrating.

In determining the specific gravity of a sample, a nomogram can be prepared as described by Waugh (5), or the total displacement of the sample can be calculated from the following formula:

Weight of Sample in grams plus Buoyancy in grams equals Total Displacement in ml. (= gm.). Knowing the total displacement and weight of the sample, the specific gravity can be calculated, and knowing the number of nuts in the sample, the mean displacement per nut can also be calculated from the total displacement of the sample. Distilled water at a temperature of 20 degrees C. should be used both in calibrating the hydrometer and in later work with it. Variations in the density of the water resulting from differences in temperature or other causes will result in errors in the data obtained with this instrument. When properly calibrated and carefully used the data obtained with this hydrometer check with those obtained when the displacement is determined gravimetrically, and there is considerable saving of time over the gravimetric method.

Separating the Sample into Several Specific Gravity Classes

The specific gravity of the sample is a measure of the degree of filling of the sample as a composite, and is valuable in comparisons because it gives this information in one statistic which can be easily used in a statistical analysis of the data. The number or weight of the nuts in the sample that have a high degree of kernel development is of interest, as are also data on those having lesser degrees of kernel development. The specific gravity of the sample shows the general degree of filling of the lot of nuts, but it is an overall measurement and does not show to what extent individual nuts composing the sample vary.

To determine the number or weight of the nuts in a sample that are of a designated class or classes having certain limits with respect to their degree of filling or kernel development, the specific gravity limits of each class are set. The next step is to select nuts of the same size and variety as the sample and then from these find individual nuts that have a specific gravity equal to the specific gravity limits of the several classes. If it is desired, for instance, to separate the nuts into four classes having the following specific gravity limits: Up to .49; .50 to .64; .65 to .74; and .75 to .82, certain nuts having specific gravities of .50, .65, and .75 would be selected out of a considerable

number tested individually. The method described by Waugh (5) could be used in selecting these nuts that are to be thus used as standards or models. The hydrometer shown in Fig. 1 and the balance shown in Fig. 2 are valuable in this work. The .50 specific gravity nuts would be floated on water and the line determined by the edge of the meniscus on the surface of the floating nut would be marked with a soft lead pencil. In this case approximately half the nut would be above the water line. The .65 and .75 specific gravity standard nuts would be floated in 95 per cent ethyl alcohol and similarly marked. After these standard nuts are removed from the liquid and have dried, an India-ink line could replace the pencil line. Some of the nuts used as standards are shown in Fig. 1. The lines on these nuts are the guide to be used in the separation of the nuts in evaluating an unknown sample. Pecan nuts of a given size that float with a greater amount of the area of the nut exposed above the liquid than is shown within the meniscus line of the model pecan nut of a similar size should have a specific gravity less than that of the model pecan nut. Conversely, nuts that float with a less amount of the area of the nut exposed above the liquid than that of the model nut should have a specific gravity greater than that of the model nut.

Ordinarily five classes have been found to be satisfactory in this work. The first class of nuts to be removed from the sample are those having a specific gravity of less than .50. These nuts are separated from those having a higher specific gravity by floating the sample in water. The nuts that show a greater area out of water than do the .50 specific gravity standard nuts are first removed from the water and set aside. The remaining heavier nuts of the sample are then removed and after drying are floated in 95 per cent ethyl alcohol at 20 degrees C (sp. gr. = .82). Here they are divided into four additional specific gravity classes by hand separation on the basis of comparison with the standard nuts. The second class has specific gravity limits of .50 and .64, and comprises nuts that float higher than the .65 standard nut; a third class has limits of .65 and .74, and is judged by using the .75 standard nut; the fourth has limits of .75 and .82, and contains remaining nuts that are not completely immersed in the alcohol; those nuts that are submerged in the alcohol by gravity have a specific gravity greater than .82 and constitute the fifth class. This last class may be divided, if desired, into two or more subclasses by successively floating the nuts in solutions having lower percentages of alcohol, and therefore greater density, than the 95 per cent solution. With each separation the nuts that float would be removed, and those that sink would then be floated in the solution of the next higher density.

In using alcohol for separating the nuts into the several specific gravity classes it was found that the density of the alcohol changes some with use, and some of the alcohol is removed with the nuts each time a sample is handled. This loss of alcohol has been found to amount to less than a gallon for each one hundred pounds of nuts separated. Starting with 1.5 liters and maintaining approximately that volume for ten hours by adding 95 per cent ethyl alcohol as necessary while separating the nuts of ninety-six samples totaling one hundred and

twenty pounds, it was found that the specific gravity of the alcohol solution had been reduced from 95 per cent at the start to 94 per cent at the finish. At 20 degrees C this is a reduction of .00281 in specific gravity which is well within the error of separation.

In this method of classifying pecan nuts, those having a specific gravity greater than .82 are classified without the possibility of error if the density of the solution used remains reasonably constant. However, in the case of the nuts separated by hand on the basis of degree of immersion, there is the possibility of making errors in judging the amount of area exposed by the floating nut as well as of making errors because of differences in size and shape of the nuts. A nut having a specific gravity of .51, for example, might be misjudged and therefore improperly placed in the class having a specific gravity of less than .50. In using the method of separating pecan nuts into several specific gravity classes as described here it has been found that the error has varied from less than five per cent to as much as eleven per cent of the nuts separated by hand. The greatest error found for a single nut has amounted to .06 difference in specific gravity reading, and the average of the errors made has amounted to .03. For any group of samples, corrections for error in separating the nuts into specific gravity classes can be made if the nuts in each of the classes have been kept separate. Specific gravity determinations for the individual nuts of a representative sample from each class can be made by the method described by Waugh. The error of separation for the class, as determined from this sample taken from the class, can then be used as a basis for adjustment, or as a check on the specific gravity of the nuts of that class.

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Immune and Resistant Cover Crops Valuable in Root-Knot-Infested Peach Orchards[1]

By C. W. McBeth and A. L. Taylor, *U. S. Department of Agriculture, Tifton, Ga.*

Peach growing in many areas, particularly in the South, has been greatly handicapped because of injury caused by the root-knot-nematode, *Heterodera marioni* (Cornu) Goodey. The object of this paper is to report the progress and results, for the first 5 years, of a long-time experiment set up to determine the effect of root-knot-immune, -resistant, and -susceptible cover crops on the root-knot-nematode population of a peach orchard. The experiment has progressed to a point that it is felt other workers and peach growers might profit by the results obtained.

Other workers have recommended the planting of root-knot-resistant cover crops for the control of this pest in peach orchards, but there are no published reports of any experiments actually set up to measure the effect of such cover crops on the root-knot-nematode population on peach or other trees nor on any other perennial plants. Watson (6) suggests that only root-knot-resistant cover crops should be grown in the peach orchard, the idea being to reduce the chances of building up a nematode population in a clean orchard. He also suggests mulching trees after they become infected.

Godfrey (2) demonstrated, in gallon cans, that the root-knot-nematode population can be greatly reduced by one or two trap crop plantings. On the other hand, Bessey (1) conducted experiments using trap crops as a means of reducing root-knot-nematode populations but without much success.

The use of root-knot-resistant rootstocks up to now has appeared to be the most successful solution to this nematode problem in instances where new orchards are to be established or old ones replanted. Tufts and Day (5), Hutchins (3), and others report Shalil and Yunnan peach varieties as being highly resistant. The experiments reported in the present paper, however, are designed as a method to control root knot in peach orchards of susceptible rootstock.

Symptoms of Root Knot Infection

In most cases root-knot-infected plants are characterized by swellings or galls on the roots. The peach root in Fig. 1 is an outstanding example of this. Ordinarily a tree heavily infected with root knot can be detected by the condition of the foliage. The leaves on such trees turn yellow, and in severe cases, the trees may become prematurely defoliated. However, other agents such as insects, and disturbances such as winter injury and drought can cause similar symptoms. Therefore, the only sure method of determining if a tree is infected with root-knot-nematode is examination of the root for the presence of the

[1]Cooperative investigations at Tifton, Georgia, of the Division of Nematology, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture and Georgia Coastal Plain Experiment Station.

FIG. 1. Photograph of peach common rootstock heavily infected with root knot.

nematode knots or galls. The knots can be easily seen with the naked eye, for they range from $^1/_{16}$ inch to 1 inch or more in diameter. The nematodes are imbedded in the knot and cannot be seen in the immature stages without the aid of a microscope. The mature females can be seen without the aid of a magnifier providing the knot is broken open and held under a bright light or direct sunlight so as to expose the pearly white pear-shaped bodies about the size of a pinhead.

Experimental Procedure

The experimental orchard is located on a well drained Norfolk sand, deep phase, which is especially favorable for development of the root-knot-nematode. Elberta peach on the common root-knot-susceptible rootstock was used. The planting originally consisted of 16 plots of 6 trees each, a total of 96 trees. The treatments listed below were arranged in a 4 x 4 Latin square:

1. Root-knot-nematode-susceptible cover crop—Whippoorwill cowpeas in the summer and Austrian winter peas in the winter, both turned under as green manure. This treatment is the common cover crop practice in this section; it will, therefore, be referred to in the future as the "control".
2. Root-knot-immune and -resistant cover crops — *Crotalaria spectabilis* in the summer and oats in the winter, both turned under as green manure.
3. Clean cultivation — Clean cultivated both winter and summer.
4. Trap cover crop — Several plantings of Whippoorwill cowpeas made during the summer and destroyed before the nematodes, in the roots, become mature.

Treatment No. 1, root-knot-susceptible cover crops, was incor-

porated in the experiment to serve as control or check. In this treatment the nematode population is increased in the areas between the trees. The other three treatments in the experiment were designed to reduce to a minimum the nematode population in the interspaces, the underlying thought being that, as the tree roots spread out into new soil each year, growing conditions would be much more favorable if the surrounding soil were free of nematodes.

Fig. 2 is an aerial photograph of the experiment. The numbers on each plot correspond to the treatments as explained above. (The last

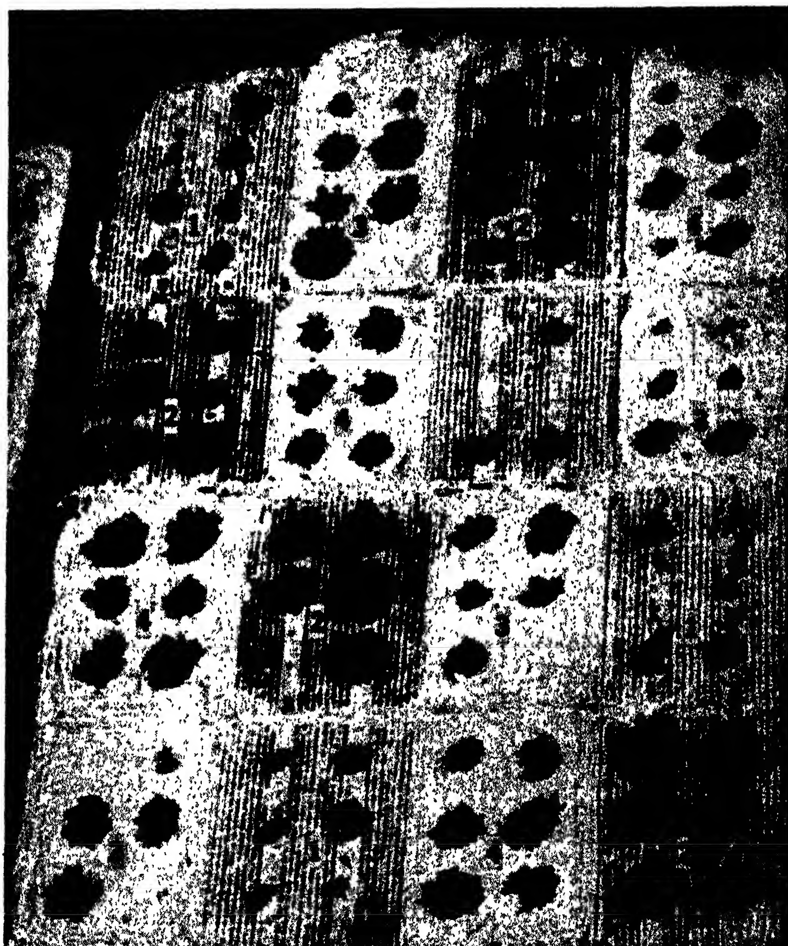

Fig. 2. Aerial photograph of experiment showing arrangement of plots. 1—control or susceptible cover crop treatment. 2—Immune-resistant cover crop treatment. 3—Clean cultivation. 4—Trap crop treatment. (Top row of trees on photograph is Yunnan P. I. No. 55885, not part of this experiment.)

TABLE I—AVERAGE NEW GROWTH AND TRUNK DIAMETER INCREASE PER TREE PER TREATMENT. NEW GROWTH MEASURED IN CUBIC INCHES, TRUNK DIAMETER TO NEAREST $^1/_{20}$ OF AN INCH

Treatment	New Growth First Year	Diameter at Setting	Diameter Increase					Total
			1939	1940	1941	1942	1943	
Susceptible cover crop (control)	51.4	0.37	0.27	1.13	0.30	0.40	0.32	2.42
Immune and resistant cover crop	97.05	0.38	0.39	1.22	0.88	1.00	0.83	4.32
Clean cultivation	147.56	0 39	0.44	1.44	0.85	0 69	0 51	3 93
Trap cover crop	194.35	0.39	0.53	1.70	0.91	0.51	0.45	4.10
Least significant mean difference, 5 per cent	42.30	—	0.08	0.35	0.36	0.24	0.43	0.91
Least significant mean difference, 1 per cent	64.13	—	0.11	0.54	0.54	0.37	0.67	1.41

row of trees at the top of the picture is extra and is not part of this experiment. These trees are 4-year-old Yunnan P. I. No. 55885.)

Except for cover crops, all plots have been given exactly the same treatment; that is, each tree has been given an equal amount of commercial fertilizer and the same treatments for insect pests and diseases. Immediately after the planting was made, each tree was pruned back to an 18-inch whip. The trunk diameter was measured, and the point at which the measurements were taken was marked with white paint in order that measurements could be taken at the same point each year. New growth measurements were taken the first year by measuring the length and average diameter of each branch or twig over 6 inches long. This was discontinued because of the tremendous amount

FIG. 3. Representative tree from control or susceptible cover crop plot.

of work involved, and also because the results corresponded almost exactly with the results of trunk diameter measurements. The per cent of root knot infection of each tree was determined by examining root samples and estimating the per cent of the root system actually disrupted by the infection. One hundred per cent infected indicates that all roots are heavily knotted and no feeder roots present. Trunk diameter increase has been measured each year for 5 years, and yield records have been taken for three seasons.

Results

The average of new growth measurements for the first year, and trunk diameter increases for 5 years are given in Table I. The amount of new growth was significantly greater in the three treatments which had reduced the amount of root knot in the areas between the trees.

The trunk diameter increase in the plots planted with immune and resistant cover crops was significantly greater than that of the control every year except 1940, the second year.

Fig. 4. Representative tree from plot planted to root-knot-immune and -resistant cover crops.

In the clean cultivation plots, the trunk diameter increase has been significantly greater than the control in three out of 5 years. The same is true for the plots where a trap crop was grown.

The average trunk diameter increase for the 5-year period is significantly greater in all three nematode reducing practices than in the control. There is no significant trunk diameter difference between any of the nematode reducing treatments for the 5-year period. It is interesting to note, however, that in the first 2 years, growth was significantly greater in the trap crop plots than in the immune-resistant plots, in the third year the increase was about the same, and in the fourth and fifth years immune-resistant plots exceeded the trap crop plots, the difference being highly significant in the fourth year.

The difference in growth between the control and other treatments can be readily seen in the aerial photograph, Fig. 2 (It is also very interesting to note that the same is true in the extra row of Yunnan trees.).

Figures 3 and 4 are photographs of representative trees from a control plot and a plot planted to root-knot-immune and -resistant cover crops. A comparison of these two photographs illustrates the great difference in growth between these two treatments.

The degree of root knot infection (see Table II) is significantly greater in the control plots than that in any of the other treatments. The per cent infection is practically the same in the clean cultivation and trap crop treatments, while the roots of trees grown in plots with root-knot-immune and -resistant cover crops are significantly cleaner than those in any of the other treatments.

TABLE II—Estimation of the Average Per Cent of Root Knot Infection of Peach Roots for Different Cover Crop Treatments

Treatment	Root Knot Infected (Per Cent)			
	1940	1941	1943	Average
Susceptible cover crop (control)	95	94	92	94
Immune cover crop	71	53	64	63
Clean cultivation	72	72	78	74
Trap cover crop	78	69	76	75
Least significant mean difference—5 per cent	13.78	15.16	10.70	10.8
Least significant mean difference—1 per cent	21 24	23 38	16 50	15.54

After the cover crop treatments had been in force for 2 years, two rows of cucumbers were planted down the center of each plot as an indicator crop. One hundred plants were taken from each treatment and examined for root knot by using the lactophenol acid fuchsin staining method, McBeth, Taylor and Smith (4). Actual counts were made of the nematodes found in each plant. The average number of nematodes per root for control plots was 105, as compared to none in the immune-resistant plots, .17 in the clean cultivation plots, and 1.75 in the trap crop plots.

Yield data have been taken for the past 3 years. Yield alone is not an accurate measure of the severity of a nematode infection, however, as there are so many other factors that influence the amount and quality of fruit produced, such as insects, weather, and various diseases. Damage from insects and diseases was reduced to a minimum by following a strict spray schedule. The average yield per tree per

treatment is given in Table III. However, frosts reduced the yields in all plots, particularly in 1943.

TABLE III—AVERAGE YIELD OF PEACHES PER TREE PER COVER CROP TREATMENT

Treatment	(Pounds) 1941	(Pounds) 1942	(Pounds) 1943	Average (Pounds) 1941–43
Susceptible cover crop (control)	12.6	5 2	5.25	7.7
Immune and resistant cover crop	41.4	65.2	26.88	44.50
Clean cultivation	42.0	24.9	11.22	26.0
Trap cover crop	41.1	29.3	14.31	28.2
Least significant mean difference—5 per cent	—	27.5	10.80	16.97
Least significant mean difference—1 per cent	—	42.48	16.65	26.16

In the first season, 1941, the treatments designed to control the nematodes produced three times as much fruit as the control. Due to the wide range of yields within treatments, however, the differences were not statistically significant.

In the second and third years, 1942–43, the yield from plots planted with the immune and resistant cover crops was significantly greater than that from the control. The differences between the control and the other treatments were not significant, however.

The average yield per tree per treatment for the 3-year period is significantly greater in all three treatments than the control.[1]

Discussion and Conclusions

The effect of the cover crop treatments has been measured in four different ways with the same results. In every case the control or root knot susceptible cover crop plots have been the least desirable. The best results have been obtained from the immune-resistant cover crop plots. The results of the clean cultivation and trap crop treatments are about equal and have been moderately good.

There are possibly three factors involved in the results obtained: competition for moisture, extra fertility from cover crops, and parasitism by the root knot nematode. The possibility that competition for moisture is the deciding factor can be eliminated, at least after the first 2 years, because the increase in growth in the immune-resistant plots, which had a heavy cover crop growth, was greater than in clean cultivation or trap-crop treatments, which had no competition for moisture. During the first 2 years when the trees were small and root systems shallow, competition for moisture was possibly an important factor. During those years, maximum growth was made by trees in the clean cultivation and trap-crop treatments.

The extra fertility from cover crop residue may partially account for the increased growth in the immune-resistant plot as compared to

[1]While this paper was in press the yields for 1944 were obtained. They were as follows: Control, 9.8 pounds per tree, Immune-resistant cover crop, 142.2 pounds per tree; Clean cultivation, 78.2 pounds per tree; and Trap cover crop, 56.1 pounds per tree. Statistically all treatments are significantly better than the control. Immune-resistant cover crop treatment is significantly greater than the other treatments.

the clean cultivated and trap-crop plots during the last 2 years. However, the control which yielded the least growth and fruit, also included heavy leguminous cover crops turned under each year. The fact that the highest and the lowest yielding treatments both comprised cover crops turned under indicates that the extra fertility added to the soil by cover crops will not overcome the effects of a heavy root knot infection on the tree roots. The logical explanation of this is that even though the extra fertility was present in the controls, the trees were not able to utilize it because of the knotted and functionally disrupted condition of the roots.

Of the four cover crop practices followed in this experiment the immune-resistant cover crop treatment was most successful and practical as it furnishes cover for the soil, reduces the nematode population and adds extra fertility. This treatment consists of growing *Crotalaria spectabilis* in the summer and oats in the winter. *C. spectabilis* is immune to the root-knot-nematode in that even though nematodes are able to enter the roots they are not able to mature and produce eggs. Oats are not entirely immune but are highly resistant, that is, nematode larvae enter the roots in small numbers and are able to reach maturity and produce eggs. As the oats are grown only in the winter when the nematodes for the most part are inactive, there is very little chance for the nematode population to be affected.

Clean cultivation is preferable to root-knot-susceptible cover crops although it is not advisable on rolling land because of soil erosion.

The trap crop method of reducing the nematode population is accomplished by planting a highly susceptible cover crop and destroying the plants before the nematodes contained in the roots have developed to maturity. This treatment requires considerable knowledge of the life history of the nematode and careful timing in destroying the cover crop, or the nematodes will be increased instead of decreased. To get the maximum effect from a trap crop, it is necessary to dissect the nematodes from the roots to ascertain their stage of growth so that the cover crop can be left as long as possible yet destroyed before the immature females have reached the critical stage where they will continue to develop and produce eggs even if the host plants are not functioning. This treatment is impractical for it involves considerable extra time and work besides requiring enough knowledge of the life history of the nematode to determine when it is time to destroy the crop. Most growers would not have the knowledge or equipment necessary to carry out this practice successfully.

Yunnan and Shalil rootstocks are undoubtedly more resistant to the root-knot-nematode than the common rootstock; in southern Georgia, however, they have become quite heavily infected after the second year. The indications are that even though Yunnan and Shalil rootstocks are used, it is desirable to grow root-knot-immune or -resistant cover crops in the orchard.

Summary

In areas where the root-knot-nematode is a problem, the growth and yield of peach trees can be significantly increased by growing

only root-knot-resistant and -immune cover crops. Clean cultivation and trap cover crop treatments also increase the yields of root-knot-infected peach trees but neither practice is practical.

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The Rooting Habit of Grimes Apple Trees Under Different Systems of Soil Management[1]

By CLARENCE E. BAKER, *Purdue University, Lafayette, Ind.*

THE root systems of 21-year-old semi-permanent Grimes apple trees under three soil management systems in an experimental orchard near Lafayette, Indiana, were studied in the fall of 1943. The soil is a typical Crosby silt loam with but minor variations over the area involved in these studies (1).

Four trees in each of the following soil treatments were examined:

(a) *Strawy manure mulch.* This plot was cultivated with a fall sown cover crop of rye or wheat for the first 12 years. Since that time, it has been in grass with a moderate to heavy mulch of strawy manure about the trees. The trees were very weak and unproductive at the time cultivation was discontinued. Soon after mulching was begun, they became vigorous and productive and during the last 8 years they have been the heaviest and most regular bearing trees in any of the three treatments.

(b) *Cultivation.* These trees have been cultivated each growing season since they were planted. Fall-sown cover crops were grown as long as a stand could be secured. After 10 years it was difficult to secure a good crop of either wheat or rye, because of the shade and the impoverished condition of the surface soil. These trees have been in an extremely weak and unproductive condition since they were 10 years old. While they have produced considerable fruit, it has been small in size and of little value.

(c) *Bluegrass sod.* Since the third growing season, these trees have been in bluegrass sod which is cut once or twice a year and left where it falls. The trees have made an excellent growth and have been consistently productive.

One half of the mulched trees, one half of the cultivated trees, and all of the trees in sod have received annual spring applications of sulphate of ammonia at the rate of ¼ pound per year of age. In the case of the mulched and the cultivated trees in these studies, two in each treatment were from the area where no nitrogen was applied, and two were from the area receiving nitrogen.

TRENCHING METHOD EMPLOYED

Preliminary studies were made on several trees, following the general method used by Oskamp and Batjer (2) and others, locating the inner face of the trench 6 feet from the trunk. This location did not appear to give a very accurate picture of the roots, especially the downward growing ones near the center of the root system. The data reported here were obtained from a 2- x 10-foot trench made on the south-east side of the trees. The west end of each trench was one foot west of the center of the trunk of the tree and the north face of the

[1]Journal Paper No. 188, Purdue University Agricultural Experiment Station.

TABLE I—AIR DRY WEIGHT IN GRAMS OF ROOTS FROM DIFFERENT SOIL LEVELS OF A 2- x 10-FOOT TRENCH

Soil Level (Inches)	Size of Roots (Inches)					Total
	0–¼	¼–½	½–1	1–2	2–up	
			Strawy Mulch Manure			
			Tree 2–4			
0–6	1,290	475	360	416	0	2,541
6–12	116	168	210	236	135	865
12–24	75	215	318	420	0	1,028
24–36	46	195	228	142	0	611
36–42	21	48	26	0	0	95
Total	1,548	1,101	1,142	1,214	135	5,140
			Tree 12–4			
0–6	580	160	98	0	0	838
6–12	155	148	152	76	0	531
12–24	115	180	370	445	765	1,875
24–36	125	76	72	0	0	273
36–42	15	33	0	0	0	48
Total . .	990	597	692	521	765	3,565
			Tree 20–4			
0–6	235	60	115	0	0	410
6–12	163	80	0	0	0	243
12–24	130	265	260	521	0	1,176
24–36	66	212	392	320	0	990
36–42	23	11	29	0	0	63
Total	617	628	796	841	0	2,882
			Tree 30–4			
0–6	360	163	178	0	0	701
6–12	251	252	154	222	0	879
12–24	134	53	111	0	0	298
24–36	125	306	193	0	0	624
36–42	7	8	0	0	0	15
Total .	877	782	636	222	0	2,517
			Cultivation			
			Tree 6–10			
0–6	156	0	0	0	0	156
6–12	219	138	110	112	0	579
12–24	122	123	229	0	0	474
24–36	60	20	0	0	0	80
36–42	6	0	0	0	0	6
Total	563	281	339	112	0	1,295
			Tree 12–8			
0–6	197	34	39	0	0	270
6–12	56	59	122	716	0	953
12–24	74	137	154	49	0	414
24–36	50	24	57	53	0	184
36–42	22	30	0	0	0	52
Total	399	284	372	818	0	1,873
			Tree 20–8			
0–6	111	11	0	0	0	122
6–12	148	119	0	0	0	267
12–24	143	207	560	987	0	1,897
24–36	60	180	198	270	0	708
36–42	14	52	22	0	0	88
Total	476	569	780	1,257	0	3,082

TABLE I—*(Concluded)*

Soil Level (Inches)	Size of Roots (Inches)					Total
	0–¼	¼–½	½–1	1–2	2–up	
Tree 30–10						
0–6	513	72	58	0	326	969
6–12	143	226	250	698	346	1,663
12–24	242	445	677	748	0	2,112
24–36	191	165	71	0	0	427
36–42	44	0	0	0	0	44
Total..........	1,133	908	1,056	1,446	672	5,215
Bluegrass Sod						
Tree 6–14						
0–6	310	66	0	0	0	376
6–12	118	107	263	0	0	488
12–24	77	116	228	0	0	421
24–36	80	169	14	0	0	263
36–42	9	2	0	0	0	11
Total..........	594	460	505	0	0	1,559
Tree 12–14						
0–6	443	175	217	0	0	835
6–12	200	228	204	0	0	632
12–24	175	395	475	865	1,235	3,145
24–36	153	430	460	171	0	1,214
36–42	23	17	0	0	0	40
Total..........	994	1,245	1,356	1,036	1,235	5,866
Tree 20–14						
0–6	291	267	63	0	835	1,456
6–12	137	79	14	0	0	230
12–24	173	370	491	370	0	1,404
24–36	71	235	266	0	0	572
36–42	46	43	0	0	0	89
Total..........	718	994	834	370	835	3,751
Tree 30–14						
0–6	232	65	302	0	0	599
6–12	189	215	107	0	0	511
12–24	115	367	445	270	0	1,197
24–36	101	63	212	0	0	376
36–42	70	150	57	0	0	277
Total..........	707	860	1,123	270	0	2,960

trench was three feet south of the same point, with the long dimension of the trench directly east and west.

The soil was removed by 6-inch levels, the roots collected, cleaned, air-dried, and weighed in the customary manner, and the inner face of each trench was mapped showing the location and diameter of each root-end exposed. The soil horizons also were located on each map.

A series of soil samples was taken to represent each horizon on the inner face of the trench near each end and at the center. Our soils department recognizes seven horizons in a typical Crosby profile A-1, A-2, A-3, B-1, B-2, B-3, and C-1 as described later. Thus a group of 21 samples was required to represent each trench.

Root Distribution

The data on root distribution by size and weight are set forth in Table I. A study of these data shows that there is a wide variation

of the root distribution between trees of the same treatment. The difference between trees of the same treatment frequently is larger than that between trees of different treatments. Consequently, at least as determined by the method used, there was little correlation between soil treatment and the distribution of different sizes of roots at different depths. No greater correlation was found between root distribution and soil profile. Roots of different sizes appeared to be equally at home in the A-3, B-1, B-2 or B-3 horizons, regardless of soil management. Roots in the A-1 and A-2 layers were disturbed to some extent by cultivation on the plot so treated.

Roots of trees in all treatments were confined primarily to the upper 24 inches of soil. The C-1 horizon, comprising the glacial till or parent material, usually began at a depth of 32 to 36 inches. This is a very hard and impervious material and is alkaline in reaction. (Table II). Only occasional roots that appeared to have grown down through soil cracks were found here. A few medium sized roots were found between 24 and 36 inches on all trees.

Soil pH Determinations

The pH of the soil samples taken from each trench was determined by means of a glass electrode apparatus. (Table II). In examining these data, it should be remembered that the west end of the trench is close to the trunk of the tree and the east end is near the extent of the branches.

The seven soil horizons existing in this typical Crosby profile may be roughly described as follows:

A-1 Surface inch; A-2, from 1 inch below the surface to plow depth; A-3, from plow depth to the change in soil texture, usually at 10 to 12 inches; B-1, an area of silt accumulation between clay aggregates resulting from leaching and usually is found at from 10 to 12 inches to 15 to 18 inches; B-2, the zone of colloidal accumulation, mottled brown and black, slightly acid in reaction; B-3, similar to the B-2 in texture tending to be more nearly neutral in reaction; C-1, the glacial till or parent soil material, which is alkaline in reaction and foams in dilute HCl, is usually found at from 32 to 36 inches down.

The effect of annual applications of ammonium sulfate over a period of 21 years upon the acidity of the soil in comparison with untreated soil, appears to have extended little below the A-3 horizon and its effect on the surface soil is not consistent in the case of all trees. Cultivated tree 30–10 received a heavy application of lime in 1938 (Table II), but none of the other trees have had any corrective treatment. There is some tendency for the surface soil under the manure mulch to show less effect from the ammonium sulphate treatment, especially when compared with the trees in sod. The surface soil of the bluegrass sod plot, all of which has received ammonium sulphate each year, is quite consistently more acid than the soil about the mulched or cultivated trees where no ammonium sulphate has been applied. Below the B-1 horizon, there appears to be few variations

TABLE II—PH OF SOIL SAMPLES TAKEN FROM NORTH FACE OF TRENCHES

Soil Horizon	Strawy Manure Mulch				Cultivation				Bluegrass Sod			
	Tree 2-4 No Nitrogen	Tree 12-4 No Nitrogen	Tree 20-4 Am Sulph	Tree 30-4 Am Sulph	Tree 6-10 No Nitrogen	Tree 12-8 No Nitrogen	Tree 20-8 Am Sulph	Tree 30-10* Am Sulph	Tree 6-14 Am Sulph	Tree 12-14 Am Sulph	Tree 20-14 Am Sulph	Tree 30-14 Am Sulph
	Near East End of Trench											
A-1	6.4	5.3	5.05	4.85	5.55	4.65	4.0	6.65	4.2	4.3	3.9	4.05
A-2	5.6	4.7	4.25	4.5	5.0	4.5	3.9	5.9	4.2	4.15	4.4	4.45
A-3	4.95	4.4	4.4	4.9	5.65	4.5	3.35	4.65	4.55	5.14	5.1	5.03
B-1	4.95	4.4	4.65	4.7	5.05	5.1	4.6	4.75	4.7	5.17	5.55	5.25
B-2	5.7	4.7	5.35	6.15	5.55	6.55	6.2	6.45	5.9	6.11	6.1	5.3
B-3	6.7	5.9	6.15	6.9	6.85	6.4	6.8	7.0	6.65	6.3	6.5	6.2
C-1	8.2	8.1	5.0†	8.2	8.2	8.25	8.0	8.2	8.3	8.2	8.2	8.2
	Center of Trench											
A-1	6.6	5.2	4.65	5.7	5.3	4.9	3.9	5.2	4.75	4.3	3.75	4.2
A-2	5.9	5.0	4.35	4.9	5.6	4.8	3.8	4.25	4.2	4.2	3.95	4.0
A-3	5.25	4.25	4.35	4.65	5.65	4.2	3.9	4.2	4.4	4.8	4.45	4.8
B-1	5.2	4.35	4.55	5.0	5.5	4.65	4.2	4.2	4.75	5.3	5.55	5.15
B-2	6.1	4.7	5.7	5.4	6.3	6.1	6.25	5.35	5.8	6.1	6.2	5.4
B-3	6.45	5.5	6.35	6.5	7.2	6.6	6.7	6.8	6.6	7.0	6.3	6.0
C-1	8.1	8.1	8.1	8.15	8.2	8.05	7.5†	8.1	8.3	8.3	8.1	6.9†
	Near West End of Trench											
A-1	5.75	4.65	4.45	5.45	5.5	4.15	3.9	4.85	3.8	3.8	3.95	3.8
A-2	5.6	4.3	4.25	4.5	5.1	4.4	3.75	4.5	3.7	4.1	3.95	3.85
A-3	5.0	4.3	4.25	4.4	4.9	4.3	3.85	4.4	4.1	4.7	4.7	4.7
B-1	4.9	4.35	4.4	4.6	5.0	4.5	4.85	4.65	4.75	5.2	5.05	4.7
B-2	6.25	5.0	5.2	5.8	5.5	5.25	6.2	5.6	5.5	6.55	5.6	5.15
B-3	7.0	6.3	6.05	6.6	6.6	6.3	6.8	6.7	6.4	6.5	6.0	5.8
C-1	8.1	8.1	8.0	8.05	7.8†	8.05	7.4†	8.1	8.1	8.3	6.95†	7.9†

*This tree is in an area that received an application of approximately 5,000 pounds of hydrated lime per acre in the spring of 1938.

†Sample taken near bottom of trench, but the true C-1 profile was not exposed at this location

in soil pH other than those probably originating from natural soil variations.

It is interesting to note that cultivated tree 30-10 to which the lime had been applied, resulting in a rather high pH figure for the upper 12 inches of soil, also had the greatest volume and weight of roots in the upper 12 inches of soil of any of the four cultivated trees. On the weight basis, tree 30-10 had 2632 grams of roots of all sizes in the surface 12 inches of soil while the total roots for the other three trees in the same soil areas was only 2347 grams. Also, mulched tree 2-4 which had a higher pH figure than the other three mulched trees in the three A horizons, had 3406 grams of roots in the upper 12 inches while the total of the other three mulched trees was 3602 grams in the same soil area. In the case of tree 30-10 especially, these figures likely are unduly influenced by a few large roots near the surface. On the other hand, these roots may have been in this location as a result of favorable soil reaction.

There was no correlation between the weight of roots found in the trenches and the yield of the trees over a nine year period. (Table III). Mulched tree 2-4, which had the highest weight of roots in the sample area, had the lowest total yield of any of the four mulched trees. Cultivated tree 30-10 was third of the four cultivated trees in total yield and sod tree 12-14 was second in its plot.

TABLE III—Total Yield, 1935–1943

Strawv Manure Mulch		Cultivation		Bluegrass Sod	
Tree	Fruit (Pounds)	Tree	Fruit (Pounds)	Tree	Fruit (Pounds)
2–4	2,315	6–10	913	6–14	3,129
12–4	3,754	12–8	2,735	12–14	3,688
20–4	3,332	20–8	3,221	20–14	4,271
30–4	3,129	30–10	2,594	30–14	3,267

Conclusions

Considering the limitations of the method of study employed and the small number of trees involved, no correlations were established between any of the three systems of soil management and effect upon root development.

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The Effects of Wire Girdles on Apple Trees in the Nursery

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The effectiveness of wire girdles in stimulating root formation on layered plants has been familiar to practical plant propagators for over two centuries, but attendant dwarfing of the portion above the girdle has been less generally recognized. In recent years suggestion has been made occasionally that wire girdles be placed around the base of the trunk of root grafted apple trees at the time of planting in the orchard in cases where scion rooting is particularly desired. Experience recounted in the present paper shows that the check in top growth consequent upon application of these girdles is great enough to warrant caution in their use for this purpose.

The data set forth here are a by-product of a study of scion rooting in certain foreign varieties of apple. The immediate purpose of this study was to classify these varieties roughly as free- or sparse-rooting, or intermediate. To this end, each variety tested was represented by 20 root-grafts, 10 of which were wired at the base of the scion and 10 were planted in normal condition; the latter were expected to reveal the very free-rooting varieties, while those which failed to emit scion roots in response to the girdling are considered sparse-rooting. The wired trees and the normal trees of each variety constituted separate plots, all planted in random arrangement. This plan was followed on three lots, each grown for two years, the first planted in 1940 and the third in 1942. With each lot Northern Spy was grown as a standard. The test included 115 other varieties, with some probable duplications of varieties obtained under different names.

Toward the close of the 1940 growing season high coloration of the foliage in some of the plots of wired trees and subsequently, dwarfing of the tops, became evident. Sprouts from the seedling stocks, as mentioned by McClintock (3), were rather abundant in the wired trees. Since the dwarfing effects seemed important enough to be reported, measurements were taken, which, combined with the routine records of scion rooting, constitute the material for this paper. Lack of space prevents publication of the record of every variety, but a sample — random so far as the growth measurements are concerned — showing some of the more extreme amounts of scion rooting is presented in Table I. Records of all the 115 varieties and three of Northern Spy are summarized in Table II.

Though the unwired ("normal") trees of the free-rooting varieties show considerable superiority in percentages of trees forming scion roots over the wired trees of the sparsely rooting varieties, the effectiveness of the wire girdles is manifest where the contrast is between wired and normal trees of the same varieties. In the moderately and poorly rooting varieties the percentage of scion root incidence in the wired trees is approximately twice that in the unwired. No comprehensive statement can be made as to the time of emergence of the scion roots; their presence in the first year has been noted in occasional observation. Howard (2) reports rather frequent forming of scion

roots on normal root grafts in the first year. The data used here record conditions at the end of the second year in the nursery, when the effects of the girdling had had ample time for manifestation.

TABLE I. Sample Records of Varietal Response to Wire Girdling in Apple Trees

P.I. No.	Variety	Year Planted	Wired		Normal		Mean Linear Growth				Index*	
							1st Yr		2nd Yr			
			Trees (No.)	With Scion Roots (No.)	Trees (No.)	With Scion Roots (No.)	Wired (Cm)	Normal (Cm)	Wired (Cm)	Normal (Cm)	1st Yr	2nd yr
30327	Kizil Alma	1941	6	6	7	7	38	39	165	635	97	26
55215	Holovouske malinowe	1941	10	10	10	9	50	43	82	164	116	50
97300	Meski	1941	10	10	9	4	37	33	405	327	112	124
104615	Newport Cross	1940	9	7	7	6	47	67	252	412	70	61
104813	Sparreholm	1940	5	5	7	6	25	29	156	211	86	79
107200	Belfler kitaika	1941	8	7	10	0	23	55	101	326	42	31
107202	Bessemianka	1941	10	10	10	3	58	63	127	373	92	34
107224	Komsomoletz	1942	8	7	9	0	67	50	52	145	134	86
107230	Oleg	1941	9	9	10	10	38	54	203	418	70	49
107237	Pomon kitaika	1942	8	8	8	0	54	69	89	226	78	39
107251	Slavianka	1940	9	9	7	5	54	22	136	142	245	96
107319	Renet Bergamotnii	1941	9	8	10	6	55	50	98	298	110	33
107321	Arkad Zimn. Zolot.†	1942	7	7	8	6	36	42	101	117	86	86
113474	Hibernal	1941	9	9	10	2	22	16	159	147	137	108
113476	Roslin	1942	7	7	10	1	32	37	84	128	86	66
113483	McPrince	1942	8	7	6	0	42	45	105	389	93	27
123991	Grover	1942	6	6	10	8	43	34	106	148	126	72
129626	Ballarat	1941	10	9	10	10	54	58	237	403	93	59
133097	Ivory's Double Vig.	1942	17	16	19	19	50	68	96	243	73	39
134590	Waukon	1942	7	6	7	3	43	34	111	144	126	77
	Northern Spy	1940	14	14	13	13	62	81	243	242	77	100
	Northern Spy	1941	8	8	10	10	43	61	204	251	70	81
	Northern Spy	1942	9	9	10	9	45	43	103	136	105	76
103442	Antonovka	1941	9	1	10	0	28	82	185	630	34	29
104514	Renetta moschata†	1941	10	5	9	3	23	40	203	347	57	58
104995	Pepin shafran	1941	8	4	10	2	42	36	130	280	117	46
107197	Antonovka shafran	1941	6	1	9	1	47	47	271	268	100	101
107201	Belfler foenicks	1940	7	4	5	1	55	54	416	544	102	76
107204	Sestra Belfl. kitaika	1941	8	2	10	5	43	78	289	493	55	59
107206	Shampanren kitaika	1940	5	3	7	3	28	26	137	172	108	80
107244	Rubinovie	1941	10	5	10	4	16	62	108	425	26	25
107253	Tayezhnoie	1941	9	3	9	2	19	27	187	301	70	62
107255	Zimnee Sladkoe	1941	10	3	8	1	32	32	191	284	100	67
107317	Paradiska Michurin	1940	5	3	9	5	19	24	104	162	79	64
113481	Thurso	1940	9	3	8	2	72	41	233	264	176	88
113831	Ostem	1942	7	1	8	0	44	12	78	64	367	122
123996	Sandow	1942	7	0	7	0	47	17	75	43	276	174
123999	Spiza	1940	6	4	8	1	50	65	220	335	77	66
125266	Devons. Quarrenden	1942	7	1	5	0	23	48	110	224	48	49
127696	Izo	1942	9	0	8	0	28	41	107	217	68	49

$$\text{*Index} = \frac{\text{Growth of wired trees}}{\text{Growth of normal trees}}$$

†Identity dubious.

In top growth during the first year, with standard errors of the means ranging from 2.24 to 3.35, none of the differences between wired and normal trees shown in Table II is significant. In the second year, however, they are pronounced and highly significant, the mean linear top growth of the normal trees amounting to 162 per cent of that of the wired. To eliminate any possible weighting of means by the presence of particularly weak or very vigorous varieties, the growth made by the wired trees was calculated, for each variety, as

TABLE II. Growth of Wire-Girdled and of Normal Apple Root Grafts in the Nursery

Scion Rooting	Varieties (No.)	Wired		Normal		Linear Growth				Index‡					
						Wired		Normal		Mean		Cases >100		Changes	
		(No.)	Rooted (Per Cent)	(No.)	Rooted (Per Cent)	1st Yr (Cm)	2nd Yr (Cm)	1st Yr (Cm)	2nd Yr (Cm)	1st Yr	2nd Yr.	1st Yr (No.)	2nd Yr. (No.)	+ (No.)	− (No.)
All kinds	118†	983	64	1007	38	38	169	43	274	103	68	53	17	24	90
Abundant	39†	338	97	351	63	45	174	49	278	110	69	17	5*	6	32
Moderate	34	287	71	274	36	34	168	39	272	100	67	15*	6	7	26
Poor	45	358	28	382	15	34	166	41	273	98	67	21*	6	11	32

*Includes 1 case where growth of wired equals growth of normal.
†Including 3 records of Northern Spy.
‡Index = $\frac{\text{Growth of wired trees}}{\text{Growth of normal trees}}$

percentage of the growth of the normal trees of the same variety. For brevity's sake, the figure thus derived is called the "index". In the absence of effect, the mean of the indices for all varieties should be close to 100; actually it is 103 for the first year. In the second year, however, it drops to 68, indicating that the effect of the girdles was not only pronounced but also general. In the 118 entries this index is above 100 in 53 cases in the first year and in 17 in the second. Since the index may change in the second year without crossing the 100 per cent threshold, the numbers of changes upward or downward, regardless of amount, are tabulated. For the whole population the decreases in the index are nearly three times as numerous as the increases, with four cases in which no change occurred. However regarded, the records show general and considerable check in top growth during the second year from application of the wire girdles.

TABLE III. Growth of Wire-Girdled and of Normal Apple Trees Paired for Presence and Absence of Scion Roots

Treatment	Pairs (No.)	First Year Growth Scion Roots		Second Year Growth Scion Roots	
		Present (Cm)	Lacking (Cm)	Present (Cm)	Lacking (Cm)
Wired	153	37	29	154	160
Normal	171	45	46	295	298

Qualitative analysis for the presence of any general tendency of scion roots to palliate or to intensify the effects of the wire girdles on top growth is afforded by the data in Tables II and III. The grouping of varieties followed in Table II was made on the basis of the percentages of scion-rooted trees in the wired plots; the figures are the means of the plot means. The second-year top growths, between which differences among the wired and among the unwired are not significant, show that the varieties falling into the three categories average substantially alike in vigor. In the first year growths the means of the

varieties classed as rooting well are significantly above those of the other groups. Since the significance does not hold over to the second year its importance seems small and it may well signify only that the girdling, with consequent scion rooting, became effective earlier and more completely on the trees making the greater initial growth.

Since the several groups, as constituted in Table II, contained various percentages of trees devoid of scion roots, an arrangement which would assort the trees more rigidly as to presence of these roots seemed desirable. Accordingly pairings of individual trees within plots were made to the extent permitted by the unequal numbers of trees with and trees without scion roots in most plots. This involved use of all the trees in the minority category in any plot; selection from the majority was made on the basis of juxtaposition to the minority trees in the row. Varieties were ignored in assembling these data for Table III, but the pairing obviously insured identical varietal composition of the populations with and without roots. The data thus available were drawn from paired records of 648 trees. Here, with varietal and treatment differences wholly eliminated, growth in the second year, when the scion roots have reached greater development than in the first, shows no significant difference due to presence or absence of scion roots, either in wired or in normal trees.

No implication as to ultimate effects of scion roots (1, 3) is intended. The point of immediate interest is the absence of any influence which might have modified the effect of the wire girdles on nursery trees. This lack seems demonstrated, in the absence of any indication in the records to justify an hypothesis of balance between stimulation from presence of scion roots in some varieties and depression from their presence in other varieties.

Wire girdling is not without usefulness. The decrease in top growth following its application is advantageous in establishment of plants wholly on their own roots, as for use as stools in mound layering. The superiority of wired trees in quantity of scion roots is greater than that shown here in percentage developing these roots. When trees are transferred to the layering beds the seedling roots are removed, and those with tops previously restricted withstand the root pruning thus involved better than those with tops reduced by pruning at the time of transplanting, which are more likely to suffer from sunscald, borers and wound infection. Varieties seem to differ in the readiness with which they overgrow the girdles and, presumably, resume normal growth; it is possible that in some the check will be of brief duration. Nevertheless, in the orchard, this restriction of top growth could well delay advent of heavy production so much that recourse to wiring should be approached with extreme caution.

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Preliminary Studies on Adapting Virginia Crab to Top-Working with Stayman[1]

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The search for superior apple stocks in Indiana was initiated in order to obtain longer lived Grimes trees. The identity of collar rot, the major cause of Grimes losses, was not known at the time these studies were started. Ample evidence was available, however, to prove that Grimes on French crab stocks were readily attacked by collar rot. As the studies with various stocks progressed data were accumulated which indicated that Grimes on Virginia Crab stocks did not succumb to collar rot. The reason for this was established when Baines (1) proved that collar rot is caused by a definite fungus, *Phytophthora cactorum*. His studies proved that Virginia Crab is resistant to the causal fungous, while Grimes, and French crab are susceptible to attack.

In the early studies of stocks in Indiana, Grimes scions were grafted directly into the trunks of the various stocks about 16 to 18 inches above the crown. This appeared to afford some protection from collar rot where Virginia Crab was the understock. When Dr. Baines established that *Phytophthora cactorum* caused collar rot he advised that susceptible varieties be top worked into resistant stocks at least 30 inches above the ground. This recommendation was based on knowledge that *P. cactorum* is a soil inhabiting fungus which produces zoospores. Such motile spores are able to move about in films of moisture, and might travel up the tree trunks and attack susceptible varieties if grafted into Virginia Crab nearer the soil. Dr. Baines' recommendation for collar rot control furnished the motive for experiments in top-working into the scaffolds of Virginia Crab. By so doing it was also possible to take advantage of the wide angled strong crotches which are characteristic of this stock. Another advantage of scaffold-working was to avoid the crotch type of winter injury to which Stayman is susceptible in Indiana, and to which Virginia Crab has proved immune under Indiana conditions thus far.

As previously reported (2) when Grimes on the various stocks came into bearing it was noted that this variety on Virginia Crab produced larger yields. This was partly the result of larger size of the trees on this stock. However, records obtained over a series of fruiting years have shown that the size of the fruits is also increased. The larger percentage of Grimes fruits 2¾ inches and up produced on the Virginia Crab stocks also accounted for the increased yields. Two of the years during which detailed yield records were being taken, that is 1934 and 1936, were the driest to date. In these drought years it was observed that Grimes on Virginia Crab suffered less than they did on any other stocks. This is explainable by an observation

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that the own-rooted Virginia Crab stocks sent their roots more deeply and extensively through the soil. In this manner they obtained moisture not available to the roots of other stocks.

The success attained with Virginia Crab as a stock for Grimes led to its being tested as a stock for other varieties grown commercially in Indiana. Among these are Delicious, Golden Delicious, McIntosh, Rome, Turley and Stayman. All said varieties were tested on trees in which the roots, trunk and scaffolds were Virginia Crab. The scion varieties were worked into the scaffolds some distance out from the crotches to avoid too compact top growth. From the beginning of these variety tests in 1936 all of the varieties except Stayman have made satisfactory top growth. Repeated attempts were made to establish Stayman tops, but most of these resulted in failure to unite with the Virginia Crab or with poor subsequent growth where union took place. Failure of the Stayman scions to unite caused these Virginia Crab stocks to be nourished chiefly by their own leaves from 1936 to 1942. During this period the Virginia Crab trees made good growth and became well established in the soil. In the spring of 1942 Virginia Crab scaffolds were cut back and again top worked with cleft and whip grafts. The scions used were from three red fruited sports of Stayman, namely, Blaxtayman, Staymared, and Scarlet Staymared. Records taken on these trees throughout the favorable growing season of 1942 indicated satisfactory growth of all three scion varieties. No breaking of grafts occurred which could be attributed to defective unions, and no pronounced overgrowths developed to indicate lack of affinity. These results were encouraging when compared with the unsatisfactory growth previously obtained with Stayman grafted on Virginia Crab.

The growing season of 1943 started favorably and ample moisture resulted in good growth of these trees throughout the summer. Periodic inspection of the trees indicated that the Stayman bud sports were making satisfactory growth on Virginia Crab stocks.

To obtain comparative data, records were taken after growth had ceased in the fall of 1943. The total growth made by each scion during the two growing seasons was recorded for all grafts made in 1942. From these measurements the average scion growth per tree was computed. It is interesting to note that in any given bud sport there was relatively little difference in total scion growth per tree. Such uniformity would be expected from a given variety propagated on a clonal stock like own-rooted Virginia Crab.

This paper is not a report on the comparative growth of all the varieties being tested in the stocks studies. It is of interest however to compare the Stayman bud sports with one another and with certain other varieties. Comparing the Stayman bud sports the uniformity of scion growth is indicated by an average of 28 inches for the shortest, 30 inches for the second and 30.6 inches for the longest growth. These averages were based on 1263 measurements of both whip and cleft grafted scions.

Judged on the basis of vegetative growth and fruit production Grimes was considered to have satisfactory compatability with Vir-

ginia Crab. The average growth of Grimes similarly scaffold-worked on Virginia Crab, growing in the same orchard furnishes a gauge by which to judge the vegetative growth of other varieties. From a total of 776 measurements of Grimes scion growth the average for the 2-year period is 31 inches.

Previously published records (3) have indicated that certain varieties have made greater growth than Grimes when scaffold-worked on Virginia Crab. While Golden Delicious headed the list for total growth as reported in 1938, the growth of Turley is now presented because of its supposed kinship with Stayman. During the years when Stayman was proving so unsatisfactory in Indiana (3), Maney (5) reported similar weak growth of Stayman in his Iowa studies. Throwing further light on the Winesap group Maney (5) states "Turley does well on Virginia Crab, while Winesap is perhaps half dwarfed."

Our results in Indiana confirm Maney's statement regarding Turley; therefore it is of interest to again call attention to the origin of the Turley variety. According to the records of the Indiana Horticultural Society, (4) Turley is a seedling of Winesap. In habit and vigor of tree growth Turley resembles other members of the Winesap group, and especially the Stayman variety. Because of verbal reports of lack of affinity between Turley and Virginia Crab the writer raises the question whether such conflicting data may be due to mixtures in scion varieties. In our Indiana studies the Turley scions were obtained directly from the parent tree, therefore there is no doubt about their trueness to variety.

While Turley and Stayman appear alike in both tree and fruit characteristics they have been conspicuous, as previously reported, for their differences in compatability with Virginia Crab. During the past two years, Turley has continued to lead in vigor of growth as indicated by an average of 44 inches for 232 measurements.

These averages of two years of growth indicate that the Stayman bud sports are nearly equal to Grimes but inferior to Turley in their affinity as judged by scion growth.

At the present stage of these studies, the writer cannot explain the differences in results obtained. To stimulate thought, discussion and further research two theories are proposed, the first is that the established Virginia Crab stocks, bearing their own, as well as Stayman leaves, have functioned essentially as Virginia Crab trees without any marked production of chemical substances which inhibit union. This permits union to take place and once this is completed the inhibitory substances are not sufficiently effective to retard normal growth. If this theory is correct we should be able to overcome affinity difficulties of this type by setting the stock trees and allowing them to become established in the orchard before grafting in the scion varieties.

Some years ago when Dr. W. Filewicz of Poland visited experiment stations in this country he studied our plots and suggested to the writer that some branches of Virginia Crab should be left in the top-worked trees where affinity with the scion varieties was unsatisfactory. He based his suggestions on his experiments in Poland in which top-worked trees on hardy stocks recovered from cold injury more readily

when stock branches had been retained as part of the leafy top. How much stock top should be retained and how long it should remain in the case of Virginia Crab are factors on which we are obtaining data in Indiana. It would be beneficial if similar data were collected at other stations where studies of affinity, and stock hardiness are under way.

The second theory to explain the congeniality between Virginia Crab, and the bud sports of Stayman where the parent variety had appeared uncongenial with this stock is that color differences in the fruits appear to be genetic changes which are retained in vegetative propagation. May there not be equal genetic differences in affinity which are not so readily observed as the color changes? If such genetic changes have taken place in affinity they might readily be in the direction of greater affinity than that of the parent Stayman toward Virginia Crab. Some credence is offered for this theory by the studies of Tukey and Brase (6) who report lack of affinity with some strains of McIntosh and Northern Spy on Virginia Crab in New York, while in Indiana the writer has obtained good unions and growth of red fruited strains of both McIntosh and Northern Spy scaffold worked on Virginia Crab.

Indexing of propagation material for freedom from virus disease is gaining support in various states as a means of assuring orchardists healthy trees. As the use of clonal stocks increases should we index varieties for affinity to insure that the most compatible strains for each stock are used in commercial propagation?

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Growth and Yield of McIntosh Apple Trees as Influenced by the Use of Various Intermediate Stem Pieces[1]

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The experiment reported herein is part of a somewhat extensive study to determine the effect of using various interstocks on yield, season of ripening of wood and fruit, color and size of fruit, and size and longevity of tree. A previous report on the performance of Steele Red trees on various interstocks was made in 1942 (1).

The choice of interstocks for this study has been based on some specifically desired effect that each interstock might have on the scion variety. Thus with Steele Red, increased vigor was the effect desired and so interstocks which might impart increased growth to the scion were chosen. In the case of McIntosh, tree vigor is normally satisfactory, but size and color of fruit under Michigan conditions is often poor. Thus early maturing interstock varieties which might effect an earlier maturity and hence higher color in the fruit of the scion variety were chosen.

Although the trees are still too young to furnish sufficient fruit for an adequate study of interstock effect on fruit color, they have shown the effect of interstocks on tree size and yield and provided some data on size of fruit. On account of crowded conditions, half of the trees were removed during the spring of 1943, so that no benefit can accrue from delaying a report on their performance.

Materials and Method

As originally planted, this block consisted of 120 trees set out in the spring of 1937 and 252 set out in the spring of 1938. The first group, which has now been growing in the orchard for 7 years, was set out in a randomized arrangement, and consisted of McIntosh double-worked on Duchess, Haas, Malling II, IX, and XII, and McIntosh interstocks. The second group of trees, now 6 years old, consisted of McIntosh double-worked on Anisim, Dudley, Hibernal, Malling IX, Malus specie[2], McIntosh, Scott, Winter, Wecota and Wetonka set out in a systematic arrangement to permit adequate distribution of each interstock throughout the block.

The method of producing the trees was similar to that used in the Steele Red block as previously reported (1), the scion bud being inserted directly into the stem of the interstock after the latter had grown for one year in the nursery.

Results

The interstock effects on the scion variety which will be discussed in this paper include color, size, and maturity of fruit, yield, size of tree, and scion-interstock ratio.

[1]Journal Article No. 695 (N. S.) from the Michigan Agricultural Experiment Station.

[2]An unknown crab with some resemblance to *Malus Zumi.*

Data were insufficient for a detailed study of fruit color. Nevertheless, notes made at the time of harvest suggested that fruit borne on trees with Malling IX interstock had a slightly higher color than fruit on the other trees. This greater color was due to the earlier maturity of fruit on these trees as shown by the fact that much of the fruit had fallen to the ground by the time fruit on the other trees was ready to pick. Fruit on trees with Malling IX interstocks should therefore be picked about a week ahead of the usual picking date for this variety.

The effect of interstock on size of fruit was of little significance. The apparent larger size of the fruit on the McIntosh/Malling IX/seedling trees, as observed in the orchard, was due to the smaller amount of foliage on these trees which tended to emphasize the color and size of fruit borne thereon. However, only by subjecting the data to critical statistical examination may the significance of the data be established.

Cumulative yields are shown in Tables I and III. In the first planting the McIntosh/Malling IX/seedling trees took the lead up to the fourth year in the orchard, after which time they were surpassed by those trees on Haas interstock. At the end of 7 years, yields on McIntosh/Malling IX/seedling trees had also been surpassed by trees on Malling II interstock. Trees on Malling XII have produced relatively small yields to date. In the second planting, trees on Malling IX again took the lead in the early years with respect to yields, only later to be surpassed by a group having a more vigorous interstock; in this case Wetanka. Until now, Scott Winter, McIntosh and Dudley interstocks, especially the latter, have induced the lowest yields in this group. The significance of yield differences as influenced by the use of various interstocks are shown in Table III. When this data is subjected to statistical analysis, the dominating effect of Haas in increasing yield is clearly shown. The effect of using Dudley interstocks, has, on the contrary, been to reduce yields quite significantly. It was unfortunate that so many of the trees had to be removed in 1943, but such is the inevitable result of close planting. Even so, the larger number of trees available for comparison previous to 1943 was advantageous in increasing the significance of the data obtained until that time.

Trunk circumference measurements have been taken each year both above and below the union of scion and interstock on each tree. Scion measurements are shown in Tables II and III. The use of McIntosh itself as interstock has produced the largest trees in nearly every case. On the other hand, as anticipated, Malling IX, when used as an interstock, has significantly reduced tree size. Between these two extremes, there are no statistically significant differences in size due to interstock influence.

The scion/interstock trunk circumference ratio as included in Table IV may have little significance, but it is interesting to note that this figure is rather consistent for each combination, and is a means of measuring and expressing different types of union in a very simple way. A number less than 1 indicates that the interstock is larger than the scion, while a number larger than 1 indicates scion overgrowth.

The figure of 0.56 for McIntosh/Malling IX/seedling and 1.13 for McIntosh/Wecota/seedling and McIntosh/Wetonka/seedling furnish the two extremes which can be readily visualized.

Discussion

The material presented in this paper is a small contribution to the knowledge being built up in this country on the part that interstocks

TABLE I. Cumulative Yields of McIntosh Trees on Various Interstocks

Number of Fruits per Tree

First Planting

	1939 3rd yr.		1940 4th yr.		1941 5th yr.		1942 6th yr.		1943 7th yr.	
Order	Interstock	Yield	Interstock	Yield	Interstock	Yield	Interstock	Yield	Interstock	Yield
1	Malling IX	4.2	Malling IX	18.2	Haas	54.3	Haas	172 ± 21.0	Haas	268 ± 57.7
2	Malling II	1.1	Haas	5.7	Malling IX	30.5	Malling IX	119 ± 5.8	Malling II	212 ± 79.2
3	Duchess	0.8	Malling II	4.7	Malling II	28.4	Malling II	115 ± 20.1	Malling IX	179 ± 19.9
4	Haas	0.2	Duchess	3.5	Duchess	24.4	Duchess	97 ± 15.5	McIntosh	155 ± 57.0
5	Malling XII	0.04	McIntosh	1.4	Malling XII	18.6	Malling XII	90 ± 14.8	Malling XII	115 ± 35.3
6	McIntosh	0.04	Malling XII	1.1	McIntosh	16.1	McIntosh	67 ± 17.0	Duchess	79 ± 35.8

Second Planting

	3rd yr.		4th yr.		5th yr.		6th yr.	
1	Malling IX	6.2	Wetonka	29.8	Wetonka	91 ± 20.6	Malling IX	99 ± 19.2
2	Hibernal	5.5	Malling IX	26.4	Malling IX	82 ± 9.8	Wecota	87 ± 27.9
3	Wetonka	2.0	M. specie	20.2	M. specie	68 ± 4.1	Anisim	85 ± 15.8
4	M. specie	1.7	Hibernal	19.4	Wecota	67 ± 10.4	Wetonka	78 ± 18.0
5	Wecota	0.9	Anisim	16.7	Anisim	60 ± 6.4	M. specie	65 ± 15.3
6	Anisim	0.5	Wecota	15.6	Hibernal	55 ± 9.6	Hibernal	62 ± 17.3
7	Scott Winter	0.4	McIntosh	12.2	McIntosh	43 ± 9.3	S. Winter	56 ± 16.2
8	McIntosh	0.3	S. Winter	8.0	S. Winter	33 ± 4.9	McIntosh	46 ± 13.0
9	Dudley	0.0	Dudley	5.4	Dudley	20 ± 4.2	Dudley	12 ± 5.1

TABLE II. Average Trunk Circumference of McIntosh Trees on Various Interstocks

	1937 1st yr.			1938 2nd yr.			1939 3rd yr.			1940 4th yr.			1941 5th yr.			1942 6th yr.			1943 7th yr.		
Order	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.	Interstock	No. Trees	Trunk Circ.
												First	Planting								
1	Haas	17	4.1	Haas	16	8.0	Haas	18	12.9	Haas	18	17.8	Malling XII	25	23.0	Malling XII	25	29.1 ± 0.67	McIntosh	18	36.6 ± 0.82
2	Malling XII	25	4.0	Malling XII	25	7.8	Malling XII	25	12.7	Malling XII	25	17.5	Haas	18	22.5	Haas	18	28.8 ± 0.68	Haas	8	32.8 ± 1.66
3	Duchess	11	3.8	Duchess	11	7.7	McIntosh	21	12.0	McIntosh	21	16.9	McIntosh	20	21.5	McIntosh	20	28.7 ± 0.93	Malling XII	7	32.5 ± 2.37
4	McIntosh	21	3.6	McIntosh	21	7.2	Malling II	19	11.9	Duchess	10	16.8	Malling II	19	20.8	Malling II	18	27.0 ± 0.86	Malling II	5	31.8 ± 1.01
5	Malling II	19	3.8	Malling II	19	7.2	Duchess	11	11.8	Malling II	19	16.0	Duchess	10	20.6	Duchess	10	26.8 ± 1.14	Duchess	4	30.8 ± 1.57
6	Malling IX	26	3.2	Malling IX	25	5.6	Malling IX	24	8.0	Malling IX	25	10.4	Malling IX	23	12.7	Malling IX	25	14.2 ± 0.65	Malling IX	17	15.2 ± 0.98

Second Planting

Order	1st yr.			2nd yr.			3rd yr.			4th yr.			5th yr.			6th yr.		
1	Wetonka	30	5.5	McIntosh	30	10.4	McIntosh	29	15.7	McIntosh	29	21.8	McIntosh	29	28.4 ± 0.61	McIntosh	13	31.8 ± 1.40
2	Anisim	22	5.3	Wetonka	30	10.0	Wetonka	30	14.8	Hibernal	24	20.0	Wescota	27	26.4 ± 0.32	S. Winter	11	30.5 ± 1.18
3	S. Winter	24	5.5	Hibernal	30	9.9	Hibernal	29	14.9	Wetonka	30	19.7	Hibernal	28	25.9 ± 0.66	Wetonka	14	29.5 ± 1.1
4	McIntosh	30	5.2	S. Winter	25	9.9	S. Winter	25	14.6	Anisim	22	19.5	Wetonka	30	25.5 ± 1.11	Hibernal	14	29.5 ± 1.41
5	Dudley	28	5.2	Anisim	22	9.8	Anisim	22	14.5	S. Winter	25	19.0	Anisim	22	25.1 ± 0.78	Wescota	13	29.2 ± 1.25
6	Hibernal	30	5.1	Wescota	29	9.7	Wescota	29	14.4	Wescota	29	19.3	S. Winter	22	25.1 ± 1.10	Anisim	11	27.9 ± 1.07
7	Wescota	30	5.0	Dudley	28	9.5	Dudley	28	13.9	M. sp.	28	18.9	Dudley	27	24.9 ± 1.0	M. sp.	13	27.9 ± 1.65
8	M. sp.	28	4.7	M. sp.	28	9.4	M. sp.	28	12.8	Dudley	28	18.5	M. sp.	28	24.6 ± 0.82	Dudley	11	27.1 ± 1.76
9	Malling IX	24	4.0	Malling IX	25	7.5	Malling IX	23	8.9	Malling IX	25	11.4	Malling IX	22	12.8 ± 0.59	Malling IX	11	13.2 ± 0.75

play in the performance of the composite tree. Such knowledge is built up first on a study of individual cases which, brought together, may furnish the basis for some general principles.

The use of Malling IX as an interstock produced the anticipated effect of dwarfing the tree and inducing early bearing and relatively

TABLE III. Significant Differences(x) of Performance of McIntosh Trees Grown on Various Interstocks Based on Data Shown in Tables I and II

First Planting

Trunk Circumference

1942

	McI.	Wec.	Hib.	Wet.	An.	Dud.	S.W.	M.S.	M.IX
McIntosh									
Wecota									
Hibernal									
Wetonka	x								
Anisim	x								
Dudley	x								
S. Winter	x								
M. sp.	x								
Malling IX	x	x	x	x	x	x	x	x	

Yields

1942

	Wet.	M.IX	M.S.	Wec.	An.	Hib.	McI.	SW.	Dud.
Wetonka									
Malling IX									
M. sp.									
Wecota									
Anisim									
Hibernal									
McIntosh	x	x	x						
S. Winter	x	x	x	x	x	x			
Dudley	x	x	x	x	x	x	x		

1945

	McI.	S.W.	Wet.	Hib.	Wec.	An.	M.S.	Dud.	M.IX
McIntosh									
S. Winter									
Wetonka									
Hibernal									
Wecota									
Anisim									
M. sp.									
Dudley	x								
Malling IX	x	x	x	x	x	x	x	x	

1943

	M.IX	Wec.	An.	Wet.	S.W.	Hib.	M.S.	McI.	Dud.
Malling IX									
Wecota									
Anisim									
Wetonka									
M. sp.									
Hibernal									
S. Winter									
McIntosh	x								
Dudley	x	x	x	x	x	x	x	x	

Second Planting

1942

	M.XII	Ha.	McI.	M.II	Duc.	M.IX
Malling XII						
Haas						
McIntosh						
Malling II						
Duchess	x					
Malling IX	x	x	x	x	x	

1942

	Ha.	M.IX	M.II	M.XII	Duc.	McI.
Haas						
Malling IX	x					
Malling II	x					
Malling XII	x					
Duchess	x					
McIntosh	x	x				

1945

	McI.	Ha.	M.XII	M.II	Duc.	M.IX
McIntosh						
Haas						
Malling XII						
Malling II						
Duchess						
Malling IX	x	x	x	x	x	

1943

	Ha.	M.II	M.IX	McI.	M.XII	Duc.
Haas						
Malling II						
Malling IX						
McIntosh						
Malling XII	x					
Duchess	x		x	x		

x - Differences significant
Blank spaces indicate differences not significant

TABLE IV—SCION/INTERSTOCK TRUNK CIRCUMFERENCE RATIO

First Planting		Second Planting	
Interstock	Ratio	Interstock	Ratio
Haas	1.05	Wecota	1.13
Malling XII	1.04	Wetonka	1.13
Duchess	1.03	*M. sp.*	1.09
McIntosh	0.99	Dudley	1.05
Malling II	0.93	Hibernal	1.00
Malling IX	0.57	McIntosh	0.98
		Anisim	0.98
		Scott Winter	0.93
		Malling IX	0.56

high yields, to be surpassed in a few years by later bearing, more vigorous trees.

The use of Haas as an interstock showed considerable promise by inducing significantly higher yields than any of the other varieties used in this experiment. The large size of trees with Haas interstocks, however, may be a disadvantage in view of the present trend towards smaller sized trees.

The performance of trees on Dudley interstocks is especially interesting in view of the results reported by Maney (2) in 1940, who observed that the use of own-rooted Dudley as a stock for Jonathan, Sharon, Delicious, Grimes and Secor strikingly reduced size of tree and fruit production. The use of Dudley as an interstock at East Lansing has also quite definitely reduced size and yield in the case of McIntosh scions.

The changing relative position of trees on various interstocks during the course of this experiment tends to emphasize the fact that the performance of such trees is closely associated with its age, and that interstock effects cannot be evaluated accurately until the tree has arrived at a certain stage of maturity or stability in its life cycle.

The apparent relative changes in performance between 1942 and 1943 may be largely due to reduced numbers in 1943. This serves to emphasize the importance of having adequate numbers in each treatment from which sound conclusions may be drawn. The increased variability in the 1943 results, due to the smaller number of replications, may be obscuring some important differences. However, these may become more pronounced in succeeding years as the yields increase and more data become available for comparison.

Conclusion

The use of different interstocks in the propagation of the McIntosh trees reported in this paper has been shown to influence tree size and yield, according to the variety used as interstock. Tree size was significantly reduced by using Malling IX as interstock. Yields were significantly increased by the use of Haas and similarly reduced by the use of Dudley interstocks. Malling IX interstocks were observed to hasten maturity and increase the color of fruit. The use of a scion/interstock ratio to express the type of graft unions is discussed briefly.

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Comparative Root-Inducing Activity of Phenoxy Acids

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In previous reports the comparative activity of phenoxy compounds has been described for different types of physiological responses such as cell elongation, modification of all plant organs, inhibition of organ growth, and parthenocarpic development of fruit. The present report summarizes the results obtained with 63 phenoxy compounds in root-induction tests on privet cuttings. A more detailed account of these experiments will appear in an early issue of the Contributions from Boyce Thompson Institute.

Privet was used as a test object and α-naphthaleneacetic acid and β-indolebutyric acid were used as standard compounds of known root-inducing activity for privet. As explained previously (1, 2, 3), cuttings of privet have proved useful for determining whether a substance or a mixture of substances has root-inducing activity and also for determining the comparative activities of different compounds in relation to naphthaleneacetic acid and indolebutyric acid. Some of the phenoxy acids [*e. g.* α –(2, 4-dichlorophenoxy)–propionic acid and α–(2, 4–dichlorophenoxy)–*n*–butyric acid] previously shown to be active at relatively low concentrations (0.3 to 3 mg/l) on privet cuttings were also active on *Celastrus scandens, Cotoneaster apiculata,* and mixed Kurume varieties of azalea (3).

Methods

Sixty-three phenoxy compounds were tested in comparison with naphthaleneacetic acid and indolebutyric acid for root-inducing activity on cuttings of privet *(Ligustrum ovalifolium)*. Five concentrations (1, 3.2, 10, 32, 64 mg/l) of each compound were used in most cases in addition to tap water controls. Several compounds were insoluble in water in the range 32 to 64 mg/l. After a 24-hour solution treatment in the laboratory at a temperature of 70 to 80 degrees F the cuttings were planted in sand in the greenhouse. Root counts and other data were recorded at the end of 4 to 5 weeks when controls had an average of one root or less per cutting. The compounds tested were phenoxyacetic acid, α–(phenoxy)–propionic acid, α–(phenoxy)–*n*–butyric acid, and derivatives of the acids or corresponding esters containing substituents in the benzene ring: of the substituted compounds tested 23 had one substituent; 24, two; 11, three; and 1 each, four and five.

Comparative root-inducing activity was based upon the influence of concentration on the average number, length, and location of roots (length of stem tissue from which roots emerged), inhibition of rooting at base of cutting, and the relative amount of swelling and proliferation of stem tissue. Since most of the active phenoxy compounds modified the roots of privet cuttings, it was necessary to make a distinction between comparative activity with reference to the induction of roots (mostly normal) in the non-toxic range, and the production of roots (mostly modified) in the toxic range. Modified roots

were characterized mainly by various degrees of fasciation from rows of two to three roots up to extreme types in which short flange-like protuberances consisted of many roots in one plane, or roundish callus-like protuberances which contained fasciated roots in two planes. The degree of modification as well as the degree of other responses increased with increasing concentration.

Results and Discussion

On the basis of the average number of normal roots, only 4 of the 63 phenoxy compounds were of high and approximately equivalent activity to naphthaleneacetic acid. These compounds (2,4,5-trichlorophenoxypropionic acid, 2,4,5-trichlorophenoxyacetic acid, 2,4-dichlorophenoxypropionic acid, and 2,4-dibromophenoxypropionic acid) induced 15 to 40 roots per cutting and exhibited good concentration effects which were similar to those resulting from treatment with naphthaleneacetic acid. Less active compounds (*p*-chlorophenoxybutyric acid, 2,4-dichlorophenoxybutyric acid, *o*-methylphenoxypropionic acid, *p*-chlorophenoxypropionic acid, phenoxybutyric acid, and phenoxypropionic acid in decreasing order of activity) induced an average of 8 to 12 roots per cutting in the non-toxic range and exhibited only a fair concentration effect. The remainder of the 24 active phenoxy compounds induced an average of less than eight roots per cutting in the non-toxic range. Seven series of five sets each of control cuttings treated at different times had an average of one root per cutting and a maximum of four roots on individual cuttings.

The following nine phenoxy compounds induced less than 8 roots per cutting in the non-toxic range but induced 13 to 38 roots in the toxic range: *m*-chlorophenoxybutyric acid, 2,4,5-trichlorophenoxybutyric acid, *o*-chlorophenoxybutyric acid, *p*-aminophenoxyacetic acid, *m*-chlorophenoxypropionic acid, 2,5-dimethylphenoxypropionic acid, *o*-chlorophenoxypropionic acid, 2,4-dibromophenoxybutyric acid, and *o*-methylphenoxybutyric acid in descending order of activity. Five phenoxy compounds (2,5-dimethylphenoxybutyric acid, potassium 2, 6-diiodo-4-carboxyphenoxyacetate, 2,4-dichlorophenoxyacetic acid, *p*-chlorophenoxyacetic acid, and *p*-methylphenoxypropionic acid) had low root count values for all concentrations (1 to 64 mg/l) but exhibited other responses typical of root-inducing substances such as swelling and proliferation of stem tissue and the emergence of roots above the basal ends of cuttings. In contrast, the 39 non-active phenoxy compounds did not exhibit any influence of concentration on number, length, or location of roots, or on the swelling and proliferation of stems. However, for this group of non-active compounds the average number of roots was greater for 16, equal for 13, and less for 10 as compared to the average value for controls.

Results of the present tests furnish information relating to structure and root-inducing activity on privet cuttings which is either confirmatory or additional to that mentioned previously (3). In general, compounds with the propionic and butyric acid side chains were much more active than those with shorter (acetic acid) or longer (malonic, valeric, caproic, lauric) side chains. The outstanding exception is the

relatively high activity of 2,4,5-trichlorophenoxyacetic acid. Chlorophenoxy compounds were more active with chlorine in the 2,4,5 and 2,4 positions than when used as a single substituent in the ortho, meta, or para positions. Phenoxyacetic acids were inactive for rooting when chlorine, bromine, or iodine were substituted in the 2,4,6 positions, when bromine was in the 2,6 and an amino group in the 4 positions, and when chlorine was in the 4 and methyl groups in the 3,5 positions. Likewise, 2,4,6-trichlorophenoxypropionic and 2,4,6-trichlorophenoxybutyric acids were inactive. The 12 dimethylphenoxy acids included four homologous series (acetic, propionic, and butyric side chains) with methyl groups in the (2,4), (2,5), (3,4), and (3,5) positions respectively in the ring. Only two of these compounds were active (2,5-dimethylphenoxypropionic and 2,5-dimethylphenoxybutyric acids). This is in contrast to the high activity imparted by chlorine in the 2,4 positions in the case of the two corresponding dichlorophenoxy acids. Thus the kind and position of the substituents are of considerable importance in determining root-inducing activity as well as the number of substituents. These results as well as those obtained previously (3, p. 506) indicate that root-inducing activity is more closely associated with the cell elongation response than with modification of organs.

The optimal concentration of most phenoxy compounds was in the range 1 to 10 mg/l. as contrasted with 10 to 32 mg/l for naphthaleneacetic acid and 32 to 64 mg/l for indolebutyric acid. Active phenoxy compounds with one substituent generally had a narrower optimal range than those with two or three substituents. The 2,4,5-trichlorophenoxy acids might compare favorably with naphthaleneacetic acid and indolebutyric acid for rooting cuttings of commercial species of plants. At concentrations of 0.05 to 1.0 mg per gram of talc, 2,4,5-trichlorophenoxyacetic acid and 2,4,5-trichlorophenoxypropionic acid have proved effective on *Ilex opaca*, *I. aquifolium*, *I crenata*, *Genista* sp., roses, apple, *Crataegus* sp., flowering apple, and tropical *Hibiscus*. In fact, a concentration of 0.1 mg/g of 2,4,5-trichlorophenoxypropionic acid proved nearly optimal for all these species whereas equivalent rooting with indolebutyric acid required 1 to 8 mg/g. Mixtures of trichlorophenoxy acids and either or both naphthaleneacetic acid and indolebutyric acid in talc powder were generally more effective than equivalent concentrations of the individual substances, particularly when the quantity of trichlorophenoxy acid was 0.1 mg or less per gram of mixture. The 2,4,5-trichlorophenoxy acids have the additional advantage over many other phenoxy compounds of not modifying shoots or roots.

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Differences in Congeniality of Two Sources of McIntosh Apple Budwood Propagated on Rootstock USDA 227[1]

By H. B. Tukey and K. D. Brase, *N. Y. State Agricultural Experiment Station, Geneva, N. Y.*

In 1934, the authors (6) reported uncongeniality of the Delicious and McIntosh varieties of apples when budded on rootstocks of USDA 227 in the nursery in three different seasons, namely, 1931, 1932 and 1933. The buds united with the rootstocks but the growth of budlings was weak for both Delicious (29 inches) and McIntosh (24 inches) as compared with the vigorous growth of Baldwin (55 inches), Early McIntosh, Macoun, and Northern Spy (54 inches) on the same rootstock. The trees of McIntosh leafed out the second season after budding but were dead at the end of that season, and the Delicious trees were dead at the end of the third season.

In addition to these reported results, McIntosh was budded to rootstocks of USDA 227 in 1940 and again in 1941, but all trees died the second season, thus making five seasons of failure.

Yet in 1929, McIntosh was successfully budded onto rootstock USDA 227, and vigorous trees were produced which showed no lack of congeniality (7). Twelve trees were planted in the orchard as 2-year-old trees in 1933, and all developed vigorously. By 1944, nine of the trees had been cut out to make room for adjacent trees, but the three which were retained were still vigorous orchard trees.

In 1943-1944, Shaw and Southwick (2, 3, 4) reported differences in congeniality of so-called strains of McIntosh when budded on USDA 227. Two of these strains, namely McIntosh R and McIntosh G were descended from known individual trees but they could not be identified one from the other by vegetative characters, and the fruits were very similar if not identical in appearance. Nevertheless, McIntosh R failed on USDA 227 whereas McIntosh G succeeded. From this experience, Shaw and Southwick suggested that the differences in congeniality observed by the authors (6, 7) between McIntosh and USDA 227 might be due to somatic variations in budding material. The present paper reports the results of an attempt to determine this point.

Materials and Methods

The rootstock USDA 227 is a clonal selection introduced by the U. S. Department of Agriculture from an open-pollinated seedling of Northern Spy selected in 1923. It is a very vigorous rootstock, which is propagated by root cuttings. Plants were secured from the U. S. Department of Agriculture in 1929 through the courtesy of G. E. Yerkes, and have been maintained and propagated on the Station grounds at Geneva since then. This material has provided the rootstocks for the trials already reported on, but was not used in the present test.

[1]Journal Article No. 609 of the N. Y. State Agricultural Experiment Station.

Instead, as an additional precaution and as a check on the rootstock material already on hand, a second lot of rootstocks of USDA 227 was secured from the U. S. Department of Agriculture in 1943 through the courtesy of Dr. E. A. Siegler. Further, one of the trees at Geneva of McIntosh/227 which had proved congenial was dug from the orchard and rootstocks were grown from it by root cuttings. The rootstocks from these two sources constituted the material lined out for budding in 1943 and used in the trials reported in this paper.

Two sources of budwood were used with which to bud these rootstocks. The one was a 10-year-old, vigorous orchard tree of McIntosh /227, designated "McIntosh 7–1", which was one of the trees propagated in 1929 and which had proved congenial with USDA 227. The other was an 8-year-old tree of McIntosh/Malling I designated "McIntosh 1–35", which was propagated in 1931 from budwood of the source which had proved uncongenial with USDA 227 in 1931, 1932, and 1933. That is, although there were no survivors of the uncongenial combinations of McIntosh with USDA 227 in 1931, 1932, and 1933, budwood from the same source proved congenial with the Malling I rootstock and was perpetuated in this way.

Fourteen each of the congenial McIntosh 7–1 and of the uncongenial McIntosh 1–35 were budded on the rootstock USDA 227 secured in 1943 from the U. S. Department of Agriculture, and four of each were budded on the material propagated at Geneva from material which had been received from the U. S. Department of Agriculture in 1929.

Results

The buds from both the congenial McIntosh 7–1 and the uncongenial McIntosh 1–35 united with the rootstocks. From 14 buds of McIntosh 7–1, 11 started in the spring of 1944, and from 14 buds of McIntosh 1–35, 8 started. All made vigorous growth for several weeks, though budlings of McIntosh 7–1 were more vigorous.

When the budlings of McIntosh 1–35 were 40 to 50 centimeters high, they were arrested in development whereas the budlings of McIntosh 7–1 continued vigorous growth and by the end of the growing season averaged 139.7 ± 3.5 centimeters in height and were characteristic of well-grown yearling trees of the McIntosh variety. On the other hand, the budlings of McIntosh 1–35 averaged only 55.9 ± 4.7 centimeters in height and the foliage was necrotic. All plants were weak and clearly uncongenial with rootstock USDA 227. The trees of both are shown in Fig. 1.

The buds on the eight rootstocks which had been propagated from the roots of the congenial tree of McIntosh/227 behaved similarly. Two budlings developed of both McIntosh 7–1 and McIntosh 1–35. The budlings of McIntosh 7–1 made vigorous growth and averaged 137.5 centimeters in height at the end of the growing season; whereas only one of the two budlings of the uncongenial McIntosh 1–35 survived, and it was only 34 centimeters in height, necrotic, and clearly uncongenial with rootstock USDA 227.

FIG. 1. Budlings propagated from two sources of McIntosh budwood on rootstock USDA *227*. Above — the congenial McIntosh 7–1; below — the uncongenial McIntosh 1–35.

DISCUSSION

It was pointed out in 1934 (6), that one of the varieties which had proved congenial with USDA *227* is a triploid variety (Baldwin) and that three of the other congenial varieties are diploids (Early Mc-

Intosh, Macoun, and Northern Spy.) At the same time, two varieties which proved uncongenial are also diploids (Delicious and McIntosh). It was pointed out further that although McIntosh failed on rootstock USDA 227 in 1931, 1932, and 1933, the closely related Early McIntosh and Macoun varieties, which are daughter seedlings of McIntosh, succeeded. Thus, no correlation was found between differences in congeniality with USDA 227 and either chromosome number or close genetic relationship. The results reported in the present paper go a step further and show differences in congeniality in budwood from two trees of purportedly the same horticultural variety, namely, McIntosh.

Whether these differences in congeniality represent differences in strains of this variety as suggested by Shaw and Southwick (2, 3, 4) or even distinct varieties as shown by Maney for the Paragon and Arkansas varieties (1) cannot be said from the data in this paper. It is common observation, however, that McIntosh fruits from different trees may vary characteristically in degree of color, such as blush and striping, and that these differences are constant in succeeding propagations.

From conversations with fruit growers and residents in the vicinity of where the McIntosh originated at Dundas, Ontario, Canada, the senior author is inclined to believe that the original McIntosh tree bore fruit of a solid red color. It has appeared to the authors that the uncongenial McIntosh 1–35 reported in this paper produces a more nearly solid red, more uniform, more trim, firmer fruit than the congenial McIntosh 7–1. Also, the trees of McIntosh 1–35 have been somewhat slower growing and somewhat later in coming into bearing. Yet it is not certain that these differences may not be due to nutrition or environment. The point can only be established when a sufficient number of trees which have been propagated from these two trees have come into fruiting and have been critically compared.

So-called "varieties" of apples are more correctly termed "clones" (5). If then, the true McIntosh is either the congenial form (McIntosh 7–1) or the uncongenial form (McIntosh 1–35) and the uncongeniality is due to a somatic change, then the other is not the true McIntosh but is more properly a distinct clone or horticultural "variety" (5).

On the other hand the congeniality or uncongeniality may be due to some other factor than genetic make-up, such as a virus or some physiological disturbance, which may be transmitted in propagation and which is not a true somatic change. In any event, the data show clearly that there are important differences in performance of budwood from trees which appear to be of the same horticultural variety as judged by gross characters and casual examination of tree and fruit. They raise the entire question (4) of a more critical review of variations or strains in horticultural varieties of deciduous fruits, in what are now considered true and fixed clones, and they become of especial significance where choice of budwood and propagation of varieties are concerned.

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Wood Type and Original Position on Shoot with Reference to Rooting in Hardwood Cuttings of Blueberry

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THE ability of the highbush blueberry to give good returns when grown under a soil-protective mulch cover on sites unsuited to arable crops has increased interest in growing it where conservation of the soil is an important consideration. Plantings have been limited by the high price of stock which, in turn, is caused by the high cost of propagation. The use of hardwood cuttings is considered to be cheaper and more efficient than other methods of propagation by most investigators and commercial growers.

The writer (2) has reported that cuttings made of wood bearing blossom buds, or of wood from which the blossom buds have been excised, root very poorly as compared to those bearing only leaf buds. The present studies were undertaken to determine whether rooting and subsequent growth are related to the location originally occupied by the cutting along the length of the shoot, and how this relation varies between vegetative shoots and flowering shoots.

Preliminary experiments in 1942 indicated that when cuttings from corresponding positions on the shoot were used, rooting was less with those from flowering shoots, (i. e. shoots bearing blossom buds in addition to leaf buds) than with those from vegetative shoots (i. e., bearing leaf buds only).

In March, 1943, 100 1-year old shoots respectively of the flowering and vegetative types were obtained from each of three varieties, Pioneer, Cabot, and June in a commercial plantation in Central New Jersey. While the shoots were selected to conform as closely as possible to a standard diameter and length, they varied somewhat and could not always be divided into an equal number of cuttings. Each shoot used in this experiment, however, contained not less than four cuttings. Hence to test the effect of position on the shoot, the two uppermost cuttings, designated as terminal and subterminal, and the two lowermost cuttings, designated as basal and hyperbasal, were taken. Cuttings were made according to the method described by Johnston (1), that is, four inches in length and cut just above and just below a bud. The unused median portions of the shoots were discarded. In order to provide a check on the consistency of observed differences in rooting, the experiment was set up in five replicate blocks. Each block contained one lot of 20 cuttings of each variety, wood type, and position.

The cuttings were set in early April in an ordinary cold frame, in a medium about 6 inches deep consisting of one-third finely divided peat moss and two-thirds clean sand, the whole being mixed thoroughly before planting. Cuttings were set in a vertical direction with the top of each cutting flush with the level of the medium. Glass sashes covered with varnished sixteen-mesh screen shades were used

on the frames throughout the summer. Readings made with a Weston photometer showed that the light intensity beneath this covering was 40 per cent of full sunlight. The sashes were removed in late August and the screen shades about 2 weeks later. Survival counts and growth measurements were made the first week in October.

The average survival for each class of cutting wood is given in Table I. These data are subjected to an analysis of variance in Table II. The analysis of variance shows that differences among varieties are highly significant. The three varieties all differed in percentage rooting. There were also highly significant differences among cuttings from different positions. The percentage of rooting increased progressively from the terminal to the basal position. The interaction of varieties and positions is significant and this results from the fact that in the basal and hyperbasal positions the variety Cabot rooted better than June, whereas in the subterminal and terminal positions June rooted better than Cabot.

TABLE I—Per Cent Survival of Hardwood Cuttings of Three Varieties of Blueberries as Affected by Position and Wood Type in 1943

(100 Cuttings in each Class)

Variety	Basal		Hyperbasal		Sub-Terminal		Terminal		Average		Grand Average
	Vegt	Flo.	Vegt.	Flo	Vegt	Flo.	Vegt.	Flo.	Vegt.	Flo.	
Pioneer	66	57	66	37	39	2	24	0	49	24	36
June	32	34	36	18	19	7	13	0	25	15	20
Cabot	63	58	44	27	11	7	6	1	31	23	27
Average	54	50	49	27	23	5	14	0	35	21	28

TABLE II—Analysis of Variance of Survival

Source of Variation	Degrees of Freedom	Mean Square
Varieties	2	110**
Positions	3	511**
Interaction of varieties and positions	6	26*
Wood Types:		
In basal position	1	5
In hyperbasal position	1	137**
In subterminal position	1	94**
In terminal position	1	59*
Interaction of varieties and wood types within positions	8	11
Blocks	4	30*
Remainder (error)	92	10

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

The vegetative wood rooted significantly better than the flowering wood in all positions except the basal. In the latter position the differences in rooting between vegetative and flowering wood was not large enough to be considered significant. The difference in rooting between vegetative and flowering wood occurred consistently in all three varieties as shown by the non-significant interaction of varieties and wood types within positions.

TABLE III—MEAN HEIGHT IN CENTIMETERS OF SHOOT GROWTH PRODUCED DURING THE 1943 SEASON BY HARDWOOD CUTTINGS OF THREE VARIETIES OF BLUEBERRY AS AFFECTED BY WOOD TYPE AND POSITION

Variety	Basal		Hyperbasal		Sub-Terminal		Terminal		Average	
	Vegt.	Flo.	Vegt.	Flo.	Vegt.	Flo.	Vegt.	Flo.	Vegt.	Flo.
Pioneer	15.2	13.6	14.9	12.0	13.5	2.5	11.9	0	13.8	9.4
June	9.5	7.2	8.9	7.3	6.2	9.1	7.7	0	8.0	7.8
Cabot	11.9	10 6	10.6	9.3	10.3	9.4	5.2	7 0	9.5	9.0
Average	12.8	11.0	12.2	10 1	11.0	8.4	9 7	—	12.0	10.5

The shoot growth, produced by each individual cutting, was measured to the nearest centimeter and the differences in mean height between the various types and positions are shown in Table III.

Comparisons between Tables I and III indicate that greater average current year shoot growth was obtained in the classes showing higher average survival. The correlation between current year growth and survival is shown in Table IV for the various classes of cuttings as well as for the replications within each class. The correlation coefficient between survival and height is highly significant for the classes (.7510), but is not significant and practically negligible for the replications within each class (—.0185). This analysis indicates that among cuttings from the various sources the factors which cause differences in survival are associated with the factors which promote their height growth. However, for cuttings of the same origin, shoot growth is not necessarily greater in lots that show a higher degree of survival.

TABLE IV—CORRELATION BETWEEN SURVIVAL OF HARDWOOD CUTTINGS OF THREE VARIETIES OF BLUEBERRY AND MEAN HEIGHT GROWTH DURING THE 1943 SEASON

Source of Variation	Degrees of Freedom	Sum of Squares of Survival	Sum of Squares of Growth	Sum of Products	Corr. Coef.
Classes of cutting	21	1,301	585.28	655 3	0.7510**
Replications within each class	72	1,005	1022 62	−18.8	−0.0185
Total	93	2,306	1607.90	636 5	

**Significant at the 1 per cent level.

The writer wishes to express his appreciation to the staff of the National Observational Soil Conservation Nursery at Beltsville, Maryland, for providing frame space and other necessary facilities for conducting this experiment, and to Dr. Henry Hopp of the Hill-culture Section, Office of Research, Soil Conservation Service for aid in planning the experiment and analyzing the data.

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A Second Report on Some Lethal Rootstock-Scion Combinations[1]

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THE authors have reported the failure of certain apple varieties and strains when budded on the clonal rootstock Spy 227 (1). This report was based on the behavior of the buds during the first season of growth. The behavior of these trees in the second season has been such that some additions may now be made to the earlier report, in which the types are briefly described.

The behavior of the different strains and varieties during the first and second years in the nursery is summarized in Table I. It will be noted that all lots that made very poor to fair growth in the first season of 1943 are now dead. During their first year, these trees not only made poor growth but showed premature leaf discoloration and defoliation and some of them died before fall. Only three lots, McIntosh G, Shotwell Delicious, and Paragon (Iowa), are now normal vigorous trees (September, 1944). Blaxtayman made an excellent growth the first season and leafed out the following spring but made no shoot growth and all trees are now dead or nearly so. McIntosh 12 and 39, Yates, and "Paragon L" grew normally the first season, but made little or no shoot growth the second season and probably

TABLE I—GROWTH OF VARIETIES AND STRAINS ON SPY 227

Strain or Variety	Growth First Year (1943)	Condition Second Year (1944)
McIntosh 12	Excellent	All alive, little new growth
McIntosh G	Good	All alive, vigorous new growth
McIntosh 39	Good	Six trees dead, 3 with weak foliage
McIntosh 45	Fair	All dead
Blackmack	Fair	All dead
McIntosh 8	Poor	All dead
McIntosh Sport	Poor	All dead
McIntosh R.	Very poor	All dead
McIntosh 1	Very poor	All dead
Blaxtayman	Excellent	One with a few leaves, others dead
Stayman	Very poor	All dead
Stamared	Very poor	All dead
Shotwell	Excellent	All alive, vigorous new growth
Richared	Poor	All dead
Starking	Poor	All dead
Delicious	Poor	All dead
Golden Delicious	Good	Dead or with weak shoots from base
Paragon (Iowa)	Excellent	All alive, vigorous new growth
M.B.T. (Iowa)	Fair	All dead
Arkansas (Mass.)	Poor	All dead
Yates	Good	Alive, little growth
Winesap	Very poor	All dead
"Paragon L"	Fair	All alive, not much new growth
Arkansas Black	Very poor	All dead
Turley	Fair	All dead

[1]Contribution No. 539 from the Massachusetts Agricultural Experiment Station.

will die. Golden Delicious made a good growth with many branches but showed premature leaf discoloration the first season. Near the end of the second season, 4 trees are dead and the other 4 have sent out a few weak shoots from near the bases of the trees; these trees will probably die.

Certain of these varieties and strains which failed on Spy 227 have grown vigorously on two clonal rootstocks Spy 227-2 and Spy 227-12, both derived from seedlings of Spy 227. Mention was made in our previous report of a few trees of Winesap, Stayman, and Paragon budded on these two rootstocks which behaved like the incompatible strains on Spy 227. These trees made no further growth and are now dead or nearly so. They are in strong contrast to the other trees on this stock which are exceptionally large 2-year trees.

FIG. 1. Left, Shotwell. Right, Richared. The Shotwell trees are healthy and vigorous. Delicious and Starking behaved like Richared.

Tukey and Brase have reported (2) failure of Northern Spy and McIntosh when worked on Virginia Crab. This uncongeniality seems to be of a somewhat different nature from that here reported. The scions united but made only very weak growth. The authors have topworked on Virginia Crab the following strains that succeed or fail on Spy 227:

McIntosh 1	Stamared
McIntosh G	Blaxtayman
McIntosh 8	Shotwell Delicious
McIntosh 12	Delicious
McIntosh R	Richared
McIntosh 39	Starking
Red Spy	M. B. T. (Iowa)
Northern Spy	Paragon (Iowa)

A "good" and a "bad" strain or variety, three to six scions of each,

were set in each own-rooted Virginia Crab tree about 4 years old. In this experiment, both kinds grew equally well during the first season.

In 1942, buds of McIntosh strains G and R were set on own-rooted Virginia Crab layers. No difference in growth was noted the first season (1943) but after two seasons' growth, all the trees of strain R are smaller with fewer branches though they have made good shoot growth in their second year. The difference is striking but appears to be different from that of trees on Spy 227. The trees of strain R are healthy but are merely smaller than those of strain G.

Discussion

It seems entirely reasonable to conclude that there is an incompatibility between the clonal rootstock Spy 227 and certain varieties and bud sports of the apple, while others grow well on this rootstock. The incompatible types grow normally on most other rootstocks, as far as known. The types chosen for this test were mostly those which we had reason to suspect might be incompatible; hence, the large proportion of failures. This incompatibility may be due to some toxic principle in the rootstock or scion which is specific for the other part of the stion. If there is a toxic principle in one part of the stion, there must be a complementary condition in the other.

Fig. 2. Left, Paragon (Iowa). Right, Mammoth Black Twig (Iowa).

The question arises as to whether the cause of the incompatibility is transferable. If so, it cannot be very virulent. The appearance of a few sick trees of Stayman, Winesap, and Paragon when budded on rootstocks 227–2 and 227–12 raises the question of the source of the difficulty in these trees, for adjoining trees, some of which must be from the same budstick as the sick ones, are perfectly healthy. All trees of McIntosh, both G and R, on Spy 227–2 and 227–12 are vigorous and perfectly healthy.

The sudden development of the disease, if we may call it such, only in the second year, as in the case of Blaxtayman, and the slow growth in the second year, as in the case of Yates, may be due to the acquirement of the toxic principle or it may be a delayed effect of something already present. It appears that the latter is the more probable situation. Experiments planned to show whether the disease is transmissible are underway.

Webber (3) discusses the somewhat similar trouble of the orange called "Tristeza" disease. This is prevalent in South Africa, Java, Argentina and Brazil, but is not known in other countries where the same stock-scion combination of sweet orange stock is extensively used. He thinks that "the foliage of the sour orange produces regularly and normally, some product of metabolism that inhibits the action and development of the virus" present in the sweet orange trees of the countries where the disease is present. We have no evidence to show whether the symptoms here reported appear everywhere when the same combination of rootstock and scion are made. It is evident that certain conditions must exist in both scion and rootstock in order to bring about the lethal effect. Whether environment plays a part is unknown.

FIG. 3. Left, Stayman. Right, Blaxtayman in June of second year. The Blaxtayman trees died by late summer.

Summary

Certain apple varieties and strains which grow normally on most rootstocks fail when budded on the clonal rootstock Spy 227 while others grow normally. The failure may appear during the first season or may be delayed until the second season. The symptoms of the trouble are reduced growth, premature leaf discoloration, defoliation and

death. Apparently the rootstock is killed, following which the scion must die. Failure must be due to specific conditions in both scion and rootstock. We have as yet no convincing evidence whether it is a communicable disease.

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Variations in Type and Germinability of Commercial Lots of Peach Seed Used by the Nursery Trade[1]

By H. B. Tukey, *New York State Agricultural Experiment Station, Geneva, N. Y.*

The nursery trade east of the Mississippi River has depended until recently upon peach pits[2] of so-called "naturals" from the Appalachian Mountain region as a seed supply for the production of seedlings upon which to bud peach varieties for nursery trees. During the decade 1930–1940, the supply of "naturals" has been greatly reduced, due in part to the phony peach disease and the campaign for eradication of wild peach trees. During the same period, severe winters have injured and killed many peach trees in commercial orchards, so that the demand for peach trees for orchard planting has greatly increased. Under this set of circumstances the source, type, germinability, and general performance of peach pits for nursery planting have become of major concern.

In 1936, the excised-embryo method was reported for securing a quick test of germinability (2, 6) of peach seed. As a direct result samples were sent to the author for testing from seed dealers and nurserymen, representing much of the peach seed used by the larger commercial nurseries east of the Mississippi River. A total of 187 samples have been tested during the 10-year period (1934–1943), including seed from Virginia, North Carolina, Tennessee, New York, Georgia, California, and perhaps other sections where origin was uncertain. The results of these tests give an indication of the types and germinability of the commercial peach pits used by the nursery trade, and form the basis of this paper.

Variations in Gross Characteristics of Peach Pits

Peach pits received during this 10-year period have varied markedly in type. Some of the seed was of so-called "naturals" from the Appalachian Mountain region; some was of known varieties from canning factories, as Elberta from Georgia and New York, and Lovell and Muir from California; and some was of mixed nature which could not be identified. In Table I are given the relative sizes and number of pits in a pound for five types commonly received. Fig. 1 pictures them.

The so-called "naturals" from the Appalachian Mountain region have been relatively uniform in size and appearance, though some lots have averaged larger than others and have varied from season to season. Pits of Lovell have been fairly uniform and Muir less so.

[1]Journal Article No. 603 of the New York State Agricultural Experiment Station.

[2]The term "seed" is popularly used in the nursery trade to denote the pit and its contents; as employed in this paper the "seed" lies within the "pit", which is the stony pericarp of the fruit.

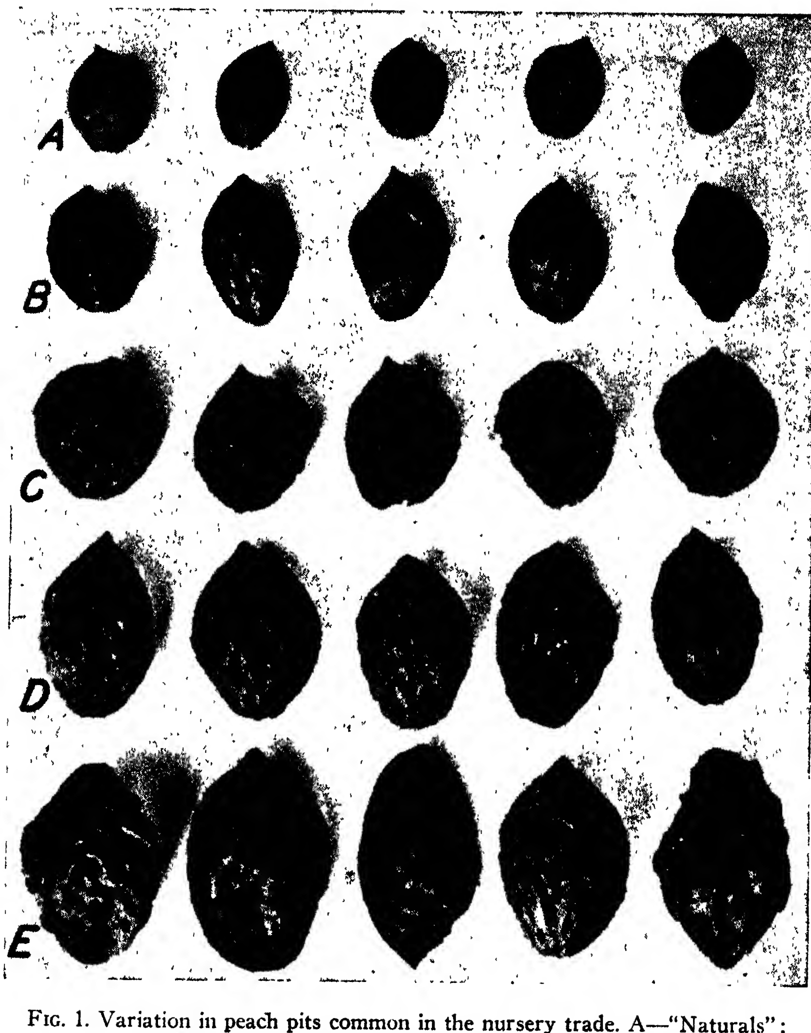

Fig. 1. Variation in peach pits common in the nursery trade. A—"Naturals"; B—Muir; C—Lovell; D—Elberta; E—"Unknown".

Samples of both have been likely to contain many split pits, sometimes as high as 16 per cent. Pits of Elberta have varied appreciably in size from different sections and different orchards and in different seasons, some that were received being even larger than the sample represented in Table I. Some lots have been clearly mixtures of several types, that is of small "naturals", large Elbertas, and various unknown types both large and small. A few samples have been of exceptionally large pits, as with the "Large unknown" in Table I. The number of pits per pound has varied from 47 to 204 — a variation of over four times.

TABLE I—SIZE, WEIGHT, AND NUMBER OF PEACH PITS PER POUND FROM FIVE TYPES COMMON IN THE NURSERY TRADE

Variety	Length (Mm)	Suture Diameter (Mm)	Cheek Diameter (Mm)	Number per Pound
"Naturals"	25.0	17.5	13.8	204
Muir	32.5	21.0	14.0	128
Lovell	34.0	27.0	20.5	82
Elberta	39.0	26.5	21.5	65
Large "Unknown"	48.0	31.5	22.0	47

VARIATIONS IN GERMINABILITY

The germinability of the 187 lots of seed received and tested during the ten seasons is shown by years in Table II, together with indications of type and source, and comments on general characteristics. Twenty to fifty pits were employed in each test.

Since the computation of percentage germination has been and should be based on the number of pits, rather than on the number of

TABLE II—RESULTS OF GERMINATION TESTS OF 187 LOTS OF COMMERCIAL PEACH SEED DURING THE 10-YEAR PERIOD 1934–1943

Lot Number	Type, Source, and Characteristics*	Germination (Per Cent)
	1934	
1	Naturals, Virginia, old, dry	0
2	Naturals, North Carolina, old, dry	10
3	Unknown, new	0
4	Chili, New York, 3 years	75
5	Naturals, Virginia, 5 years	66
6	Naturals, Tennessee, new	100
7	Naturals, Tennessee, 2 years	100
8	Naturals, Tennessee, new	67
9	Mixed, North Carolina, large, uncleaned	0
10	Mixed, North Carolina, large, uncleaned	16
11	Unknown, North Carolina, large, new	0
12	Mixed, unknown, old, dry	10
13	Mixed, North Carolina, old, dry	45
14	Mixed, unknown, old	45
15	Mixed, unknown, old, dry	30
16	Mixed, unknown, old, dry	0
17	Mixed, North Carolina, old, dry	0
18	Naturals, North Carolina, old, dry	23
19	Naturals, North Carolina, old, dry	40
20	Naturals, North Carolina, old, dry	0
21	Naturals, North Carolina, old	0
22	Naturals, Tennessee, old	20
23	Mixed, North Carolina, old	0
24	Mixed, Tennessee, old	40
25	Mixed, North Carolina, old	0
26	Mao-Tao, U.S.D.A., new	79
27	Naturals, Tennessee, old	0
28	Naturals, Tennessee, old	11
29	Mixed, Virginia, new	25
30	Naturals, Virginia, old	0
31	Mixed, Virginia, new	3
	1936	
7	Mixed, Virginia, new	33
8	Naturals, Tennessee	27
9	Naturals, Tennessee	32
10	Naturals, Tennessee, old	35
11	Unknown, North Carolina, old, charred	0
12	Naturals, Tennessee, new	74
13	Naturals, Tennessee, new	90
14	Naturals, Tennessee, new	55
15	Naturals, Virginia, old	90
16	Naturals, North Carolina, old	0
17	Naturals, Georgia, new	85
18	Naturals, Georgia, new	46
19	Naturals, Tennessee, new	56
20	Naturals, Tennessee, new	97
21	Unknown	70
22	Unknown	86
23	Naturals, Tennessee	67
24	Naturals, Tennessee, old	57
25	Naturals, Tennessee, old	53
26	Naturals, Tennessee	64
27	Naturals, North Carolina	47
28	Naturals, North Carolina, old	87
29	Naturals, North Carolina, old	87
30	Naturals, Tennessee, new	73
31	Naturals, Virginia, old	90
32	Naturals, Tennessee, old	40
33	Naturals, Tennessee	45
34	Naturals, Tennessee	60
35	Naturals, Tennessee	0
	1937	
1	Unknown, North Carolina	62
2	Naturals, Virginia, old	76
3	Naturals, Tennessee	48
4	Naturals, Tennessee	36
5	Unknown, North Carolina, old	60
6	Naturals, Georgia, old	60

"Old" indicates

TABLE II—*(Concluded)*

Lot Number	Type, Source, and Characteristics*	Germination (Per Cent)
	1935	
1	Unknown	14
2	Unknown	23
3	Mixed, Tennessee, flesh adhering	80
4	Mixed, North Carolina	4
5	Naturals, Virginia	82
6	Naturals, Virginia	100
7	Mixed, North Carolina	36
8	Mixed, Tennessee	10
9	Naturals, Virginia	10
10	Naturals, Tennessee	4
11	Naturals, Virginia, old	73
12	Naturals, Tennessee, old	87
13	Mixed, North Carolina, old, charred	0
14	Lovell, California, new	70
15	Mixed, North Carolina	5
16	Unknown	0
17	Unknown	45
18	Naturals, Tennessee	10
19	Naturals, Tennessee	0
	1936	
1	Naturals, Tennessee	55
2	Unknown	86
3	Mixed, North Carolina, old	0
4	Mixed, North Carolina, old	0
5	Mixed, North Carolina, old	0
6	Mixed, North Carolina, old	60
	1938	
15	Naturals, Tennessee	77
16	Naturals, Tennessee	63
17	Naturals, Tennessee	40
18	Lovell, California, new	81
19	Unknown	61
	1939	
1	Naturals, Georgia	75
2	Naturals, Tennessee, new	73
3	Mixed, North Carolina	58
4	Lovell, California, new	84
5	Muir, California, new	100
6	Naturals, Tennessee	21
7	Mixed, North Carolina	58
8	Naturals, Tennessee, new	54
9	Naturals, Tennessee, old	60
10	Mixed, North Carolina	50
	1940	
1	Naturals, Tennessee, new	77
2	Unknown, North Carolina, old	20
3	Unknown, North Carolina, old	50
4	Unknown, Virginia, old	67
5	Lovell, California, new	50
6	Naturals, Tennessee, new	80
7	Naturals, Tennessee, new	62
8	Naturals, Tennessee, new	60
9	Elberta, Georgia, old	51
10	Unknown, Tennessee, old	60
11	Unknown, North Carolina, new	41
12	Naturals, Tennessee, new	48
	1941	
1	Naturals, Tennessee, new	43
2	Naturals, Tennessee, new	70
3	Lovell, California, new	90
4	Unknown, North Carolina, new	90
5	Unknown, North Carolina, old	16
6	Naturals, Tennessee old,	80
7	Naturals, Tennessee, old	62
8	Naturals, Tennessee	31
9	Naturals, Tennessee, old	9
10	Naturals, Virginia, old	58
11	Elberta, New York, old	78
12	Lovell, California, new	68
13	Naturals, Tennessee	61
14	Naturals, Tennessee	75
15	Unknown, Georgia	70
16	Unknown, North Carolina	48
17	Unknown	34
18	Muir, California, new	90
19	Lovell, California, new	100
	1938	
1	Mixed, Georgia, new	14
2	Naturals, Tennessee, new	60
3	Naturals, Tennessee, new	40
4	Naturals, Tennessee, old	63
5	Naturals, Virginia, old	16
6	Naturals, Virginia, old	35
7	Naturals, Tennessee, new	32
8	Naturals, Tennessee, new	75
9	Unknown	12
10	Mixed, North Carolina, new	54
11	Mixed, Tennessee	40
12	Naturals, Georgia	52
13	Mixed, North Carolina, new	72
14	Mixed, North Carolina, old	48
	1941	
7	Unknown, Ohio, old	0
8	Naturals, Tennessee, old	70
	1942	
1	Naturals, Tennessee, old	10
	1943	
1	Naturals, Tennessee, new	85
2	Naturals, Tennessee, new	0
3	Unknown, Tennessee, new	83
4	Naturals, Tennessee, new	0
5	Unknown, Tennessee, new	15
6	Naturals, Tennessee, new	54
7	Lovell, California, new	38
8	Naturals, Virginia	33
9	Unknown, Pennsylvania	22
10	Lovell, California, new	0
11	Mixed, North Carolina	20
12	Elberta, Georgia, old	45
13	Mixed, Tennessee, old	5
14	Mixed, Tennessee, old	30
15	Mixed, Tennessee, old	100
16	Naturals, Tennessee, old	0
17	Naturals, mixed, old	70
18	Naturals, mixed, old	5
19	Mixed, North Carolina, new	48
20	Mixed, North Carolina, new	30
21	Lovell, California, new	0
22	Mixed, North Carolina, old	85
23	Naturals, Tennessee, old	45
24	Mixed, Tennessee, large	20
25	Naturals, Tennessee, old, uncleaned	89
26	Unknown, North Carolina, new	36
27	Naturals, Tennessee, old, charred	0
28	Naturals, Tennessee, old	55
29	Naturals, Tennessee, old	0
30	Mixed, North Carolina, new	40
31	Unknown, North Carolina, old	0
32	Unknown, Tennessee, old	0
33	Unknown, North Carolina.	0

*"Old" indicates 1 year or older, but of undetermined age; "New" indicates the same season.

well-developed seed, those samples which have a high proportion of split pits and abortive embryos naturally show a much reduced figure of percentage germination. Yet in such lots of pits the well-developed seed may test high in germination, as the figures for three lots of seed show in Table III. These figures emphasize the importance of examining the pits to see how many sound seeds are included, even before any test of germinability is made. They also suggest a possible improvement in the quality of commercial peach seed by cracking the pits by some cheap mechanical means, separating out the well-developed seed of known viability, and handling just the seed rather than the entire pit in commercial channels.

TABLE III—COMPARISON OF THE PERCENTAGE GERMINATION OF A SAMPLE BASED ON THE TOTAL NUMBER OF PITS VERSUS THE NUMBER OF WELL-DEVELOPED SEED

Lot and Year	Germination Based on Total Number of Pits (Per Cent)	Germination Based on Number of Well-Developed Seed (Per Cent)
Lot 11—1934	20	80
Lot 7—1938	54	70
Lot 7—1943	38	75

Not only may there be considerable variation in germinability between different lots of peach pits, but there may also be considerable variation between different samplings from large lots. For example, one sample of seed was received which showed higher than 75 per cent germination; a second sample from a different part of the large lot showed a much lower germination. Samples were then taken from each of ten 100-pound bags of seed in the lot, with the variation shown in Table IV.

TABLE IV—VARIATIONS IN GERMINABILITY OF TEN SAMPLES OF PEACH SEED TAKEN FROM EACH OF TEN 100-POUND BAGS CONSTITUTING A COMMERCIAL LOT OF PEACH PITS

Lot No.	No. Pits	Germination (Per Cent)	Lot No.	No. Pits	Germination (Per Cent)
1	50	18	6	50	32
2	50	8	7	50	44
3	50	12	8	50	34
4	50	28	9	50	22
5	50	78	10	50	8
			Average	100	28

DISCUSSION

Germination:—The large number of samples of low germination is significant; 99, or slightly more than half of the lots, were 50 per cent or less in germination; 71 were 33 per cent or less in germination; 45 were 10 per cent or less in germination; and 32 showed no germination. Only 12 lots of the 187 were 90 per cent or above in germination.

Region of Seed Production:—There has seemed to be no outstanding superiority of seed from one section over that from another.

Seed of both high and low germination was secured from the same general regions of production.

Varietal Differences:—It is known that early-ripening varieties have a high percentage of abortive seed (5, 7) and that late-ripening varieties have a high percentage of viable seed. The recognized types or varieties commonly met in the nursery trade, as "Naturals", Lovell, Elberta, and Muir are of the mid-season or late-ripening varieties. They generally showed better germination than mixed lots and "unknown" types, which may have contained seed from earlier-ripening sorts. Yet the superiority of named varieties or types was not always the case, and some of the lots showing highest germination were of nondescript mixtures.

Condition of Pits:—Dirty, uncleaned pits have given both poor (Lots 9, 10 — 1934) and good germination (Lot 25 — 1943) and have been no better and no worse than clean washed pits (Lot 11 — 1934; Lot 14 — 1935; Lot 4 — 1939; Lots 10, 21, 31, 32 and 33 — 1943). Some of the highest germinations and some of the lowest germinations were found among both types. Some lots with dried flesh still adhering showed good germination (Lot 3 — 1935). On the other hand some lots were charred as though by heat, and these showed no germination (Lot 13 — 1935, Lot 11 — 1936, and Lot 27 — 1943).

Age of Seed:—The nursery trade has at times shown a preference for 2-year-old seed, and at other times for seed of the current season. It was not possible to determine the age of most of the seed received except that some lots were dry and brittle and very likely more than a year old. One lot which had been kept in dry storage for 3 years (Lot 4 — 1934) showed 75 per cent germination, and another lot which had been kept similarly for 5 years (Lot 5 — 1934) showed 66 per cent germination. Seed of the current season, in general, showed no better and no poorer germination than seed a year old, though very old seed has shown lower germinability than newer seed.

Differences Between Years of Production:—Nurserymen are of the opinion that peach seed is of higher germination one season than another. There is some indication from the data in Table II that this may be true. Thus the seed received during the seasons of 1934, 1935, and 1943 showed more lots of low germination than the season of 1937. Yet it must be remembered that the data is for samples *received* during that year and includes samples from previous seasons as well as the current season. Accordingly, it may be that the years of low germination in the table are associated with the size of crop, in which a season of low crop yield and higher prices may attract seed from unreliable sources. It is known, however, that with some varieties of peach, as Muir and Lovell, there may be a greater number of "split pits" one season than another (1, 4), and it is also known that embryos of split pits are aborted or checked in development to some degree and are lower in storage reserves than embryos from non-split pits (7). It seems not unlikely that both of these factors may be operative and may play a part in the variation in germinability of seed from one season to another.

Curing and Handling:—In view of the fact that so many lots of

current season seed have shown no viability although upon cursory examination it has appeared firm and well developed, it is suspected that the manner in which the seed is handled after removal from the fruit may be an important factor in determining germinability. As has been mentioned, some lots of pits have appeared charred, as though from heat, and have shown low or no germination.

It is well known, too, that unclean peach pits with flesh adhering, placed in piles, may ferment and develop high temperatures. The author, in gathering cherry seed from piles of cherry pits at canning factories, has encountered temperatures within the pile which prevented securing samples with an ungloved hand. It is also well known that piles of peach pits at canning factories are turned now and then to prevent charring. Further, excessive exposure to the direct rays of the sun at high temperatures may result in the exposed pits reaching high and injurious temperatures.

Some Characteristics of Pits and Seed of the Muir and Lovell Varieties

Because of the interest in and dependence upon California peach pits, the following additional notes are recorded for the Lovell and Muir varieties.

Muir:—The Muir pits received have varied in size from large to small, have been rather lacking in general uniformity, and have been frequently split, so that many of the seeds have been free from the pit. As many as 7 pounds of loose halves of pits have been included in 100 pounds of pits. A representative sample of 100 seed taken from Muir pits shows the following general characteristics:

12 shrivelled seed, of which 10 (83 per cent) germinated
28 gummy seed, of which 7 (25 per cent) germinated
12 "double" seed, of which 10 (83 per cent) germinated
48 "typical" seed of which 43 (89 per cent) germinated
Total of 100 seed, of which 70 per cent germinated.

Including both of the double seeds in some pits, the average was 80 peach seedlings from 100 pits. Muir seedlings are less tall and more compact than Lovell seedlings and more difficult to bud because of a low branching tendency. They have a tinge of red which identifies them easily from the more common commercial varieties budded on them.

Lovell:—The Lovell pits received have been medium in size and fairly uniform, with few broken pits and fewer loose seed and halves of pits than Muir. A representative sample of 100 seed taken from Lovell pits shows the following general characteristics:

29 shrivelled seed, of which 18 (62 per cent) germinated
4 "gummy" seed, of which 4 (100 per cent) germinated
4 "double" seed, of which 3 (75 per cent) germinated
63 "typical" seed, of which 56 (89 per cent) germinated
Total of 100 seed, of which 81 per cent germinated.

Lovell seedlings are straight and willow-like and easy to bud because of the absence of low branches. They are easily identified from Elberta

seedlings but more difficult to distinguish from some of the Canadian varieties.

Samples of Muir and Lovell have been received which averaged 90 per cent or better in germination (Lots 18, 19 — 1937; Lot 3 — 1941); others contained not a single viable seed (Lots 10, 21 — 1943); and still others were intermediate between these two extremes (Lots 5 — 1940; 14 — 1935; 12 — 1937; 18 — 1938; 4 — 1939; 5 — 1940; and 7 — 1943). Apparently there is nothing in the nature of the varieties themselves which precludes a satisfactory supply of seed.

Conclusion

The wide variation in type and general gross characteristics of peach pits and the large number of samples of low germinability show the importance of establishing a uniform and reliable supply of peach seed for the nursery trade. Sufficient quantities of seed of good performance have been encountered to make it apparent that such a possibility already exists. The large number of split pits and abortive seeds which have been observed in some lots, coupled with the high germinability of the well-developed seeds in such lots, suggests the possibility of improving the quality of commercial peach seed by cracking the pits by some cheap mechanical means, separating out the well-developed seed of known viability, and using just the seeds rather than the entire pit in commercial channels.

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The Excised-Embryo Method of Testing the Germinability of Fruit Seed with Particular Reference to Peach Seed[1]

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IN 1936, following the successful artificial culture of excised immature embryos of deciduous fruits (7, 8) a rapid method was suggested for testing the germinability of non-after-ripened peach seed (9) in which embryos of mature seed[2] were similarly excised and placed in culture bottles. It was devised to meet the demand by the nursery trade for a quick test which could be used for the current season's supply of seed for fall planting and which would expedite commercial movement of seed of known germinability. Peach seed otherwise requires a period of after-ripening of approximately 10 to 12 weeks at a temperature of 2 to 5 degrees C before it will germinate (4, 6).

This paper presents data covering experiences with the excised-embryo method over a 10-year period (1934–43), giving comparative figures for the same lots of seed tested by the excised-embryo and after-ripening methods, and giving a few details and modifications in the use of the excised-embryo method.

THE METHOD

The method in general consists in removing the seed coats and vestiges of nucellus and endosperm and placing the naked embryos in a moist medium favorable to germination, such as damp peat moss (2), moist absorbent paper (2, 5), or ⅔ per cent agar in half-ounce screw-capped bottles (9). At room temperature (20 degrees C), viable embryos will evidence signs of germination within 2 to 3 days, and will give a clear cut record of germinability in 7 to 10 days.

EXCISING EMBRYOS

Preparatory to excising peach embryos from the seed, peach pits are conveniently cracked in a heavy nut cracker[3] or by placing them on a wooden block with the dorsal suture against the block and striking on the ventral suture with a hammer. No breakage of the seed itself should be experienced. Plum and apricot pits are also easily opened in this way. Cherry pits are best opened by holding them with the dorsal suture against a wooden block, and pressing downward with a heavy blade so as to split the pits along the ventral suture.

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[1]Journal paper No. 607 of the New York State Agricultural Experiment Station.

[2]The term "seed" is popularly used in the nursery trade to denote the pit and its contents; as employed in this paper the "seed" lies within the "pit", which is the stony pericarp of the fruit.

[3]"Klean Kracker", manufactured by B. M. Daniel, Harrisburgh, Pa.; "Squirrel Nut Cracker", manufactured by Alex Woldert Co., Tyler, Tex.

To facilitate removal of the seed coats, the seed should be soaked in water for several hours, as overnight. After the seed coats are softened, a cut may be made through them along the edges with a sharp knife, being careful not to cut too close to the micropylar end so as to avoid injuring the hypocotyl. Beginning at the chalazal end, the seed coats and vestiges of nucellus and endosperm may then be peeled downward in two complete plates or sections. The same general procedure may be used for the other stone fruits and for the apple and pear. The mucilageneous coating on apple and pear seeds, which makes them difficult to hold, may be removed by washing in calcium hypochlorite solution.

Contamination and Disinfectants

Viable embryos will generally show evidences of germinability before contamination can develop to such a degree as to interfere with the test. Nevertheless, reasonable precautions to reduce contamination, especially by molds, is worthwhile. Ordinary precautions of cleanliness have been found helpful, such as thorough washing or even sterilizing of germination chambers, and the use of new, clean culture media for each test. Soaking the seed in water for 16 or 17 hours has definitely reduced contamination.

A disinfectant may be used, such as a solution of calcium hypochlorite as suggested by Wilson (10). The solution is prepared by mixing 10 grams of fresh commercial calcium hypochlorite (chlorate of lime) in 140 cc of water, and filtering. The liquid should have a slight yellowish tinge and will approximate closely 20,000 ppm of chlorine. A 5-minute immersion of naked embryos in the solution with frequent shaking to remove air bubbles from the embryos, has seemed maximum, as shown in Table I. The solution does reduce contamination, but it also may either delay or inhibit development of the embryo, as the data in the table show. Although this solution was used for several seasons in the course of these studies, it has been

TABLE I—Effect of Calcium Hypochlorite Solution (20,000 ppm Chlorine) on Contamination and Germination of Excised Peach Embryos in Culture in Glass Bottles

Treatment	Germination (Per Cent)	Serious Contamination Within 10 Days (Per Cent)
	Carolina Naturals	
None	80	40
5 minutes	80	10
30 minutes	50	10
2 hours	20	0
4 hours	10	0
24 hours	0	0
	Elberta	
None	60	50
5 minutes	60	20
30 minutes	30	20
2 hours	0	0
4 hours	0	0
24 hours	0	0

abandoned since contamination is not severe when the precautions are observed which have been mentioned. Further, the viability of embryos can be determined before any contamination develops to such a point that it becomes a disturbing factor.

It has been found good practice, so far as concerns reduction of contamination, to excise the embryos in a room other than that in which the naked embryos are transferred to the germination chambers or culture media. A room free from plant materials and similar organic materials, and with windows and doors closed to reduce air currents, makes a very satisfactory transfer room.

Germination Chambers and Media

Containers and media which will provide a fairly uniform supply of moisture to the seed along with adequate aeration have been found satisfactory for the test. Originally, an agar medium in small glass bottles was used but the methods commonly used in seed germination tests as suggested by Flemion (2, 3) and employed by Heit and Nelson (5) have been found just as good and much simpler. Nevertheless the agar-bottle method is useful for certain phases and may be described.

Agar Media in Bottles:—Square half-ounce glass bottles with metal screw caps have been used containing about 5 cc of $2/3$ per cent agar (Fig. 1). Various nutrient media have been tried, consisting of different sugars and minerals but they have seemed of no added value. Sugars favor the development of contaminations and may inhibit embryo development to some degree.

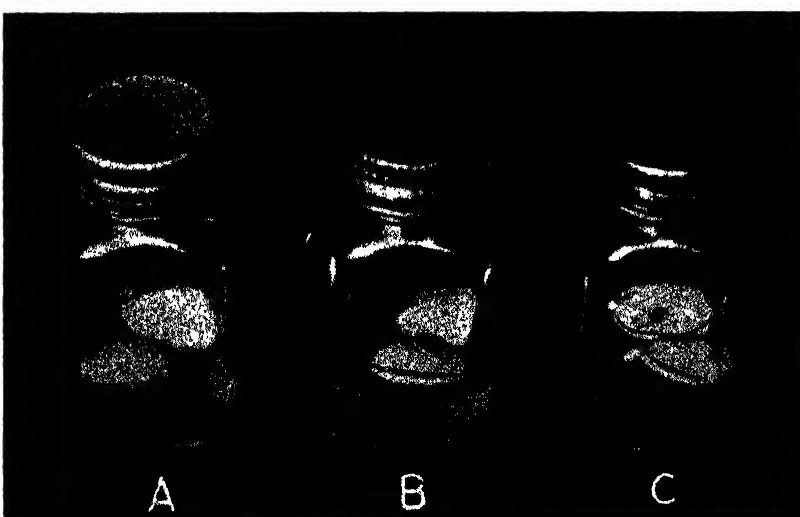

Fig. 1. Excised non-after-ripened peach embryos cultured in half-ounce bottles on $2/3$ per cent agar showing both the method and the degrees of embryo response. A — no response and non-viable; B — slight separation of cotyledons and viable; C — actual germination.

The exact percentage of agar is a most important consideration. A convenient way to prepare the medium is to boil 6⅔ grams of agar in 1 liter of water, place the unfilled bottles in rows, and fill with a pipette, placing about 5 cc in each bottle. The bottles may be placed in greenhouse flats, autoclaved for 15 minutes at 15 pounds pressure, and chilled and stored in a refrigerator. Unless the medium is cooled rather rapidly after preparation, it is likely to be hydrolized to such a degree as to become liquefied and unusable.

Transferring the embryos to the bottles is done handily with a small wire loop slightly smaller in diameter than the embryos, inserted in a glass rod. The caps should be screwed down lightly. Two embryos may be placed in each bottle but one is better; there is some indication that an embryo which fails to develop may inhibit another in the same container. The use of a room free from plant materials and similar organic matter, as has been suggested, helps to reduce contamination.

The agar-bottle method provides an excellent germination chamber with an adequate and uniform moisture supply, without drying out, and with need for no additional attention after the test is begun. It is well suited to investigational work. Contamination is more serious than in the other methods here described unless the suggested precautions are followed.

Petri Dishes:—Closed Petri dishes lined with wet filter paper have proved very satisfactory. A 100-mm dish accommodates a sample of 10 to 20 peach embryos (Fig. 2). Counts can be made clearly and rapidly. It is necessary to add only 1 or 2 cc of water every second or third day to maintain an adequate moisture supply. There should not be so much water in the dish as to cover the paper, or it may interfere with aeration of the embryos and reduce or delay germina-

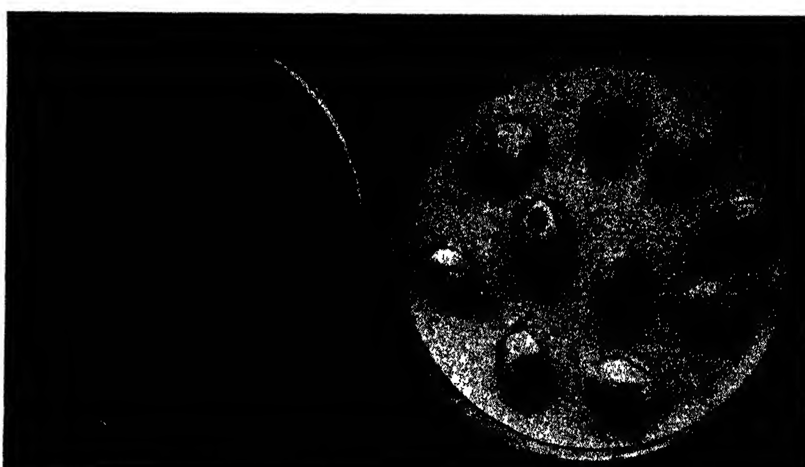

FIG. 2. Petri-dish method, using moist filter paper, showing separation of cotyledons and actual germination (100 per cent viable) of excised non-after-ripened embryos.

tion. Blotting paper, paper towelling, or agar may be used in place of filter paper.

China Plates:—The common seed germination method employing wet blotting paper in a china plate covered by an inverted plate of similar size is also satisfactory. Attention is required to maintain a uniform moisture supply since evaporation is greater than from Petri dishes. Water should be added each day, or perhaps twice a day, as needed. Embryos are not so easily observed as by other suggested methods unless a glass plate is used for the cover.

Plaster Blocks:—A good general purpose germinator is one employing a plaster block set in a glass covered dish provided with a vent for aeration (Fig. 3). It can be kept clean easily, and requires the addition of water only every 3 or 4 days.

Wet Cloth:—The common "rag doll" method used for germination tests for farm seeds is also satisfactory, in which the embryos are wrapped in wet cloth or wet paper. Drying out is likely to occur unless

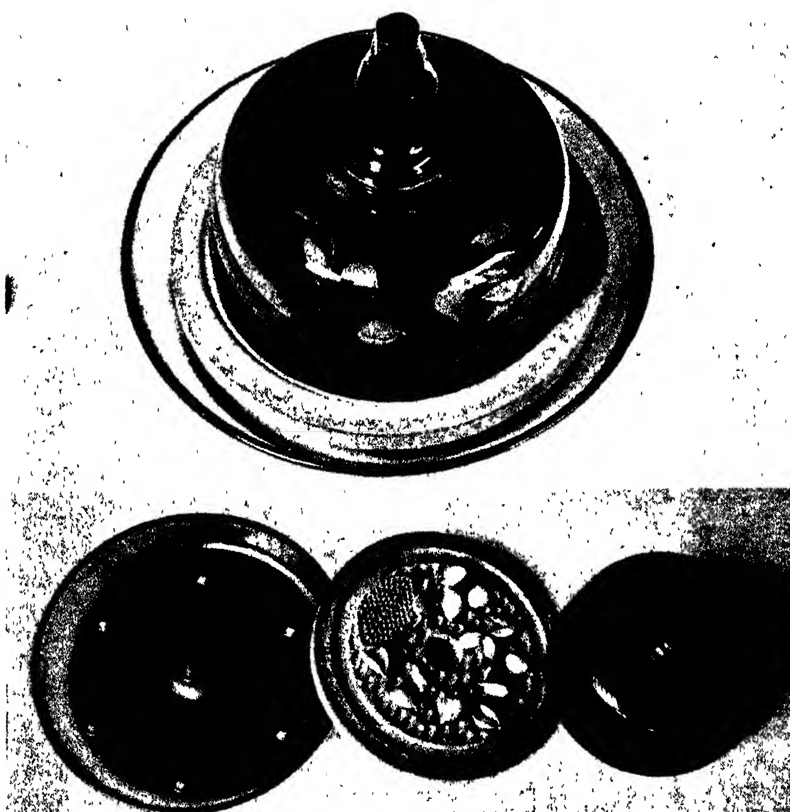

FIG. 3. A useful general purpose germination chamber with plaster block (100 per cent viability).

daily attention is given; and if the wrapping is too wet, aeration may be unfavorably reduced. The embryos are less easily observed than in other methods.

Temperatures

Room temperature (20 degrees C) has been found satisfactory at which to culture excised embryos. Higher temperatures (30 degrees C) have favored mold development and have apparently retarded embryo development appreciably.

Effect of Storage at 5 Degrees C:—In view of the fact that after-ripening of unexcised embryos at 5 degrees C for 10 to 12 weeks is essential to germination, tests have been made to see whether similar cold treatment of excised embryos might aid in germination. Storage in culture bottles at 5 degrees C and removal at various intervals up to 127 days has neither improved nor reduced germination. When removed from the cold temperature and placed at room temperature (20 degrees C), viable embryos have started immediately to develop. The results are shown in Table II. It is interesting that embryos can be kept quiescent at this temperature for so long a period and that they will respond so promptly when removed to conditions favorable to germination.

TABLE II—Germination of Excised Peach Embryos Stored at 5 Degrees C for Varying Interval of Time

Variety	Percentage Germination Following Storage at 5 Degrees C for Period Noted				
	None-Check	24 Days	60 Days	98 Days	127 Days
Mixed	20	20	20	26	20
Mixed	0	0	0	0	0
Mixed . . .	12	10	10	12	10
Mixed	58	55	50	50	55
Mao Tao	24	20	25	25	24
Mao Tao . . .	78	75	75	75	75
Naturals .	84	84	80	80	80

Criteria of Germinability

Embryos of different lots and of different species respond differently, as shown by Flemion (3). Some embryos respond by germinating and making typical seedling development, that is, vigorous root and shoot growth and greening of the cotyledons. In the case of other embryos, the cotyledons may separate and spread to 90 degrees with the central axis. With others, the cotyledons may separate only 1 or 2 millimeters (Fig. 4). Records have been kept of the numbers of embryos showing different degrees of response, and these have been compared with the germinability as measured by the after-ripening method. When all embryos are included which show even minor degrees of response, the figures are comparable, indicating that all degrees of response must be included in determining percentage germinability.

FIG. 4. Criteria of germinability of excised non-after-ripened embryos. A — no response, non viable; B — slight separation of cotyledons, viable; C — actual germination.

ACCURACY OF THE EXCISED-EMBRYO METHOD

The accuracy of the excised-embryo method of testing germinability of peach seed, in comparison to the after-ripening method is shown in Table III. The figures for both methods agree closely, the excised-embryo method giving a higher value in thirteen instances and slightly lower values in five instances. Similar figures are given for Mahaleb

TABLE III—COMPARISON OF EXCISED-EMBRYO AND AFTER-RIPENING METHODS OF TESTING GERMINABILITY OF PEACH SEED

Lot	Type, Source, and Characteristics	Germination (Per Cent)	
		Excised-Embryo Method	After-Ripening Method
	1934		
9	Mixed, North Carolina, large	0	0
10	Mixed, North Carolina, large	16	16
12	Mixed, unknown, old, dry	10	12
13	Mixed, North Carolina, old, dry	45	53
14	Mixed, unknown, old	45	35
15	Mixed, unknown, old, dry	30	26
16	Mixed, unknown, old, dry	0	0
17	Mixed, North Carolina, old, dry	0	0
18	Naturals, North Carolina, old, dry	23	23
19	Naturals, North Carolina, old, dry	40	22
20	Naturals, North Carolina, old, dry	0	0
21	Naturals, North Carolina, old	0	0
22	Naturals, Tennessee, old	20	16
23	Mixed, North Carolina, old	0	0
24	Mixed, Tennessee, old	40	24
25	Mixed, North Carolina, old	0	0
26	Mao-tao, U.S.D.A., new	79	82
29	Mixed, Virginia, new	25	23
	1935		
6	Naturals, Virginia	100	86
7	Mixed, North Carolina	36	25
8	Mixed, Tennessee	10	0
11	Naturals, Virginia, old	73	65
12	Naturals, Tennessee, old	87	75
13	Mixed, North Carolina, old	0	0
14	Lovell, California, new	70	74
	1939		
8	Naturals, Tennessee, new	54	55
9	Naturals, Tennessee, old	60	58
	1943		
7	Lovell, California, new	38	33
8	Naturals, Virginia	33	33
10	Lovell, California, new	0	0

cherry, Myrobalan plum, apricot, apple, and pear in Table IV. They also agree closely but show a slightly higher value for the excised embryo method in seven instances and a lower value in three instances.

TABLE IV—Comparison of Excised-Embryo and After-Ripening Method of Testing Germinability of Cherry, Plum, Apple, Apricot and Pear Seed

Year	Germination	
	Excised-Embryo Method (Per Cent)	After-Ripening Method* (Per Cent)
	Mahaleb	
1936	76	70
1937	38	30
1938	87	90
1938	51	50
1940	30	30
1942	95	100
	Myrobalan	
1936	50	50
1937	62	50
1940	50	50
	Apple	
1936	84	80
	Pear	
1936	92	100
	Apricot	
1939	90	88
1940	92	90

*Approximation from examination of large lots ready for spring planting. No exact counts made.

Finally, in Table V are given nurserymen's records of field performance of large plantings of peach seedlings which have been sampled and tested by the excised-embryo method. The figures for germinability are higher than the actual production of seedlings in the field but this is not surprising since factors other than germinability influence the stand of seedlings, such as season, temperature, and rainfall.

TABLE V—Comparison of Excised-Embryo Test of Germinability of Peach Seed and Extensive Nursery Field Records of Stand of Seedlings

Location	Nursery Field Performance*			
	No. Planted	No Seedlings Produced	Percentage Stand of Seedlings	Germination by the Excised-Embryo Method (Per Cent)
Geneva, N. Y	200,000	16,000	8	16
Geneva, N. Y	50,000	45,000	90	100
Dansville, N. Y	150,000	50,000	33	35
Dansville, N. Y	150,000	50,000	33	38
Monroe, Mich	600 750,000	40,000	5-7	18

*Estimates by nurserymen of approximate number of seed planted and approximate stand of seedlings.

The sample selected and the size of the sample are definitely limiting factors in the accuracy of the method. Where large quantities of seed are involved, such as with carload lots, samples should be taken from several parts of the car. If possible it is best to take a sample from each separate bag or container, and keep records for each, or to mix the lots thoroughly so that samplings from different portions of the lot will be representative. Tests of samples from 10 bags of peach pits comprising one commercial lot have varied from 8 to 73 per cent germinability. Samplings of less than 20 individuals have been found unreliable except as a rough approximation of germinability, and 50 individuals are better.

The figure of germinability desired by those dealing commercially with pits of the stone fruits is the number of seedlings likely to be secured from a given number of pits. Accordingly the percentage germination of samplings of stone fruits should be based on the number of pits in the sample rather than on the number of seeds secured from the pits.

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Some Methods Used in Breeding Peaches in New Jersey[1]

By M. A. Blake, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THERE are times when the most important problem in the commercial production of any fruit is the securing of a better variety or a series of varieties. When consumers or processors of fruits no longer want a variety, no amount of cultural skill can produce it at a profit. Consumer and market demand is continually changing and more rapidly than formerly.

In 1914, the approved commercial list of peach varieties for New Jersey included Greensboro, Carman, Hiley, Belle, Elberta, J. H. Hale and the less commonly grown Fox Seedling and Iron Mountain. Today, only Elberta and J. H. Hale of those eight varieties are planted.

Such varieties as Greensboro, Carman and Hiley were the first to become unprofitable. As a result, growers planted mostly Elberta and J. H. Hale for a few years. It soon became apparent that it would be impossible to establish a sound and profitable peach industry on two varieties.

The modern need in New Jersey is for a series of both yellow and white fleshed varieties of high market and edible ripening throughout the season from July 15 to October 1, varieties that will be acceptable for both canning and freezing as well as for eating fresh. In other words, general fruits are needed.

Maximum hardiness is desirable but it is not the most important problem. Such varieties as Greensboro, Carman, Dewey, Rochester, Gold Drop, and Chili are very hardy but New Jersey markets do not want them. A little less hardiness is acceptable in exchange for better market qualities.

Peach breeding was undertaken on a large scale at Vineland, New Jersey, in 1914 when several entire trees were covered with cheese cloth tents. Since little information was available, the need was recognized at the start for facts about the inheritance of peach characters. Certain varieties including Early Crawford, Greensboro, Belle, Elberta, Mayflower, and St. John were selected and crossed in 1914. Later, the J. H. Hale was selected as the pistillate variety most likely to provide some of the qualities desired in the improved varieties. Facts about the inheritance of single characters were discovered and reported (1). Even more important, however, from the standpoint of the main objectives, it was learned that certain varietal entities tend to be dominant over others.

A few examples are as follows: The varietal entities of Chili, Iron Mountain, P. I. 55564, Drawf Blood, and *Prunus kansuensis* were dominant over J. H. Hale. Not all of the characters of any one of these varieties were dominant over those of J. H. Hale but the majority

[1]Journal Series paper of the N. J. Agr. Exp. Sta. Rutgers Univ. division of Hort.

were, particularly the tree type and the fruit appearance. J. H. Hale, however, reduced the hardiness of the progeny of varieties which normally exceeded it, as for example, Chili.

It was noted early in the work that certain progeny were more resistant to drought and to insect and disease pests than others, and produced a more uniformly large number of fruits. It might have been possible over a long period of time and at considerable expense to learn the specific characters or combinations of characters responsible for such results before varietal breeding was attempted. But such a procedure was impractical where improved varieties were urgently needed and such an objective might not have obtained state financial support.

Carman was a leading commercial variety in 1914, was hardy and productive, and sold well in the large eastern markets but it lacked the qualities to compete with yellow-fleshed varieties. Hence, one of the first objectives of the breeding work was to replace Carman. Two varieties were offered to growers in 1925, Cumberland, a white, and Golden Jubilee, a yellow-fleshed variety. Each was decidedly superior to Carman for New Jersey. Since then, Raritan Rose has replaced Cumberland, and Triogem and Newday have, to some extent, replaced Golden Jubilee.

Hiley was first replaced by Eclipse and the latter by Goldeneast and Sunhigh. Belle was replaced by Summercrest and Fox Seedling by Afterglow. Growers requested a variety to ripen between Goldeneast and Summercrest and Pacemaker was offered. None of these varieties are regarded as perfect for New Jersey. In fact, the present program aims to replace them by better ones. This illustrates how modern demands have changed since peach growers depended upon the discovery of some chance seedling for varietal improvement in contrast to having a new variety bred to order for a specific season and purpose.

The replacement of several commercial peach varieties by new and better ones for specific seasons of ripening is a major problem and demands certain requisites if it is to be successful soon enough to be of any value to the present generation of fruit growers. The following may be listed as prime essentials:

1. Since a minimum of 4 to 5 years is required to make a cross and obtain the first fruits, perhaps from 2 to 5 years more to really evaluate the variety, and in addition, 3 to 4 years for the growers to plant orchards and bring trees into commercial bearing, it is apparent that constant effort must be made to reduce the time factor in all operations from actual crossing to the placing of trees of selected varieties in the hands of producers.

2. More is involved than the problems of actual breeding. Getting the new variety from the doorstep of the breeder to that of the grower is included. The breeder of peaches has one advantage over a breeder of a plant that is propagated only from seed since the peach may be propagated by budding as soon as a desirable combination of characters is obtained.

3. The work must be on an extensive scale and pursued without interruption for a period of not less than 15 years.

4. He must be able to judge and evaluate plants as single living entities largely by observations in the orchard, combined with acid, sugar, and tannin determinations of the fruit in the laboratory and controlled measurements of hardiness.

5. The breeder must become familiar with both the external and internal characters of the peach as a plant, its environmental requirements, and how certain characters and factors are linked with or influence the effect of another.

Such a program necessitates a considerable collection of peach varieties, species, and types. At the New Jersey Station in 1926, there was a collection of 334 varieties, species, and types. Cooperation with the U. S. Plant Introduction Bureau has resulted in a special unit of varieties called the "Foreign Legion."

Some Details of Procedure

For crossing, entire trees are covered with cheesecloth tents. These are maintained over the trees until the fruits are at least 1 inch long, since such a cover protects the flowers and young fruits to some degree in unfavorable weather and is helpful in the control of curculio. When the fruits are mature, they are picked and the seeds or pits removed. The procedure then follows one of two courses. If a cross is between varieties that mature later than August 1 in New Jersey, the seeds are stratified in shallow flats of moist sand and placed in a cool cellar until March. At that time, the kernels are removed from the bony endocarp. If the shells of any pits have not split, they are cracked. The kernels are then placed in shallow flats of sand and stored in a cool place until soil and weather conditions permit planting in nursery rows. Procedure No. 2. If the varieties crossed ripen their fruit before August 1 and thus contain so-called non-viable pits, they are handled by the pure culture method previously reported (2).

Orchard Culture

A field adapted to the culture of peaches is well fertilized with calcium, phosphorus, and potassium, as well as nitrogen, in order to insure a good growth of the seedlings. Unless lime is applied, the pH of the soil at the Horticultural Farm is 5.0 or less. The trees are set about 10 feet apart in. rows 20 feet apart or about 200 trees to the acre. This is to make sure that the trees have plenty of room in one direction and permits reasonably good tillage and spraying. Since about 35 acres of land are maintained in peaches at New Brunswick, one planting immediately follows the removal of another. The seedling trees receive very little pruning the first two seasons in order to bring them into bearing as quickly as possible. Any trees which qualify for extended tests receive the standard pruning annually thereafter.

Beginning of Selection of the Progeny

The progeny of peach crosses at New Brunswick are selected for three classes or purposes. 1. Those of value as parents for further breeding. 2. Those of immediate commercial merit. 3. Those which

are of value as distinct types and deserving of study. The first year that the trees bloom and bear fruit, detailed records are taken on each tree. These include artificial dormant bud hardiness tests by the New Jersey method, a notation of the flower type, and whether fertile or sterile. Six different fruit characters are described or rated. Edible quality is rated on a basis of ten. Acid and tannin determinations are made annually of the ripe fruits of all special selections and sometimes of all seedlings in a cross.

A rather liberal standard is followed in the culling of trees during the first season of fruiting. If a tree appears to be injured in any manner or weakened by drought, it is carried for further test. If a seedling appears promising for any purpose, a minimum of five trees are budded in a Station peach nursery comprised of from 4,000 to 6,000 stock trees each year. This is to guard against the loss of any single promising seedling by winter injury, borers or accident, and to learn its behavior when grown in the nursery. Three such propagated trees are usually planted a year later in another location on the Horticultural Farm to observe the new variety under conditions other than those under which the original tree was planted. Occasionally a seedling is so promising when it fruits for the first time that a minimum of 50 to 100 trees are budded. In such a case, the increased number of budded trees is to provide propagating wood and a few trees for special tests.

If a seedling proves to be of promise a second or third season, it receives more careful study, and hardiness, acid, tannin, and canning and freezing tests. It frequently happens that as many as three seedlings are close competitors for a single place on a commercial variety list. One is usually selected as best but the others receive further tests. In a period of 19 years, no seedling originally rated as second best has ever replaced a seedling rated as number one.

The commercial rating of a seedling is not based exclusively on normal New Jersey climatic conditions. At New Brunswick, New Jersey, climatic conditions vary sufficiently from year to year so that a variety expert can form a very accurate estimate of how a seedling will respond in other peach districts. For example, in 1944, there were 30 days in July and August when the maximum temperature was 90 degrees F or above and there were 38 clear days. Acid and tannin content of peaches were especially high. In certain other seasons, the summer climate is quite similar to that of districts farther north. A seedling is not discarded if it is considered to have worthwhile promise for any commercial peach region. A collection of more than 250 varieties, species, and types from all over the world is now available at New Brunswick for comparison with new seedlings. Ambergem, a non-melting canning variety, now grown extensively in Michigan, is an illustration of the selection and retention of a variety of merit, but not desired commercially in New Jersey.

When a new variety has demonstrated its merit and been given a name, state experiment stations requesting trees have been supplied with a limited number free of charge. It is not the policy of the Station

to recommend the new varieties in other states. It is the belief that the pomological staff of each state may best do that.

How a Seedling is Designated

When a seedling is assigned a place and planted in the orchard, it receives a number, as, for example, 36723. That signifies that it is seedling number 367 of the cross made in 1923. If a new seedling shows sufficient promise and is approved for a statewide test, it receives an introduction number, in this instance, N. J. 82. Should it prove acceptable under commercial test, it is then named. For example, N. J. 82 has now become Sunhigh.

Statewide Tests

During the first 12 to 15 years of the peach breeding work, trees of a new variety were distributed in small lots of five trees among a number of cooperators throughout the state for tests. This procedure has been discontinued. Five trees was found to be too small a number to receive a good commercial test. Few commercial peach growers in New Jersey now care to test fewer than 25 trees of a variety, and many, not less than 100 trees.

New Jersey Peach Council

By 1928, it appeared certain that improved varieties could be bred and a so-called New Jersey Peach Council consisting of ten practical growers was appointed by the President of the New Jersey State Horticultural Society to cooperate with the Experiment Station in regard to peach breeding problems and particularly to work out a satisfactory method of propagation and distribution. This council of growers meets at New Brunswick at least once during the fruiting season and together with the Chief in Horticulture decides what new seedlings, if any, will be propagated and to what extent. The Council then arranges with a nurseryman for the number of trees of the several varieties to be propagated. The Council decides annually how the available trees shall be distributed, the price, and the number to be sold to any one grower. Approximately two-thirds of all the trees in commercial orchards in New Jersey now consist of varieties developed at the New Jersey Station.

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Breeding Plants for Adaptation, Freedom from Insect Injury, and Disease Resistance[1]

By Brooks D. Drain, *University of Tennessee Agricultural Experiment Station, Knoxville, Tenn.*

The South, from a breeder's point of view, has its own peculiar problems. Winter injury in Tennessee, for example, is different from winter injury in New England. Plants otherwise hardy start growth during a warm period in mid-winter and are injured by cold that follows. Plants that blossom early are often injured by late freezes or heavy frosts. In fact, the writer regards unseasonable cold periods fairly characteristic of a large area in the Southeastern States. Peach trees that remain comparatively dormant during warm spells in winter, and pear trees that blossom late, have an advantage.

We may think of the dust bowl as a drouthy area, but the Southeast often has severe drouths also. Continuous warm temperatures and the low humus supply in many southern soils probably are important factors in the drouth response of plants. Irrigation may solve the problem for some growers, but it is important that varieties for this region shall have a reasonable ability to withstand dry weather.

Long periods of warm, dry weather result in comparatively high soil temperatures. At Knoxville, 100 degrees F in the top inch of soil during the warmest part of the day is not uncommon. Such soil temperatures appear to be unfavorable for red raspberries, lilac, blue grass and other plants. But these growing conditions are characteristic of this region, and the breeder should meet the challenge to the best of his ability.

Root-knot nematode injury occurs widely in the warmer parts of the United States, and tolerance or resistance to this pest is highly desirable. Species and varieties differ decidedly in their ability to avoid injury by nematode. The breeder needs to consider this in planning his breeding work.

The long growing season in the South is favorable for insect and disease development as well as for plant growth. We spend millions of dollars annually on insect and disease control. Why not spend thousands on the breeding of varieties that escape these troubles? Reasonable resistance to certain diseases and ability to escape certain insect injuries are requirements in many southern breeding projects.

Recent introductions show progress in meeting these requirements. The Waite pear appears to be resistant to the canker form of fire blight. Many other hybrid pears are being tested in breeding plots. While the Van Fleet raspberry was lacking in quality, it grew well in the South. Dixie, a red raspberry introduced from North Carolina, shows similar adaptation and is of better color than Van Fleet. Blakemore and other new strawberries are replacing the older sorts. Early-ripening, quality varieties of peaches from several experiment stations

[1]Records previous to 1931 were kept by J. A. McClintock and H. L. Fackler. E. M. Henry, 1932 to 1935; Arthur Meyer, 1938–39; D. M. Bailey, 1940–41; and D. S. Burgis, 1943–44, assisted with this project.

have replaced a part of the Elberta acreage in recent plantings. Youngberries and Boysenberries have been a real addition to the vining, or dewberry group of fruits, and few growers now plant the smaller-fruited, older sorts.

The progress shown by new varieties of fruit is matched by recent vegetable introductions. Wilt-resistant tomatoes and watermelons are widely grown. The African squash is practically free from pickle worm injury. Earworm-resistant sweet corn from Texas and other stations is being given extensive trial. Jersey Redskin Irish potato, a fall-crop variety, is noted for disease resistance. Urd hybrid beans developed by A. B. Strand suggest the possibility of garden beans that escape at least a part of the injury from Mexican bean beetle.

It is reasonable to assume that all this is just a beginning. The possibilities in the combining of species or very different varieties to secure new selections have only begun to be realized. Why spend millions of dollars and endless labor on curing the ills of poorly adapted, disease and insect-susceptible varieties when a few thousands spent on breeding would give us enduring improvement in material? Some of these new combinations may, and probably will, develop failings, but skillful recombination should give some relief.

The problems of technique are likely to vary with each kind of plant and each project. The way we solve these problems has a great deal to do with our accomplishments. Perhaps it is worth while to discuss a few of these problems, illustrating them with slides. The first picture is of *Rubus macrocarpus*, the giant blackberry of South America. Seedlings failed to survive our summers until we grew them in a chamber supplied with refrigerated air. A spray of cold water applied during the warmer part of the day reduced the temperature and watered the seedlings. The plants were less sensitive to summer temperatures the second season. Canes rarely develop to over 6 or 8 feet in length and showed no signs of blossoming. Additional illumination each day gives promise of enabling the plants to develop blossoms. A similar problem with red raspberry varieties from England that failed to thrive in Tennessee climate was met by the importation of plants not cut back, and the fruiting of the plants in a greenhouse, after which the parent plants were discarded.

Spring weather in Tennessee often is unfavorable for gathering pollen and hybridizing. Strawberries, raspberries, blackberries, and some of the vegetables usually have been managed in the greenhouse. Late-blossoming dwarf pear trees have been managed in a greenhouse to secure earlier blooming. Bouquets of pears gathered a week or two before the blossoms open can be forced in the greenhouse, and give a good supply of pollen. Pollen storage with humidity of about 50 and temperature about 45 degrees F has been very useful in making a supply of pollen available at all times. Enclosing large trees in tents, or structures made in part of hotbed sash, helps to reduce freezing injury in the spring. Orchard heaters were used around hybridized trees. The set of fruit from hand pollination has often been very meager when temperatures were low during pollination.

The production of excessive amounts of hybrid seed will enable the

breeder to maintain his work in spite of low viability and severe seedling losses in the flat or plant bed. Henry (1) found, in germinating strawberry seed, that comparatively high temperatures increased germination. Hybrid pear seed is often separated from the fruit in August, and if stratified at once it will be starting to grow by late November. Many small seedlings were lost in the greenhouse during the winter. Storing seed dry permits the timing of germination so that it occurs at a more favorable season.

The writer has no solution for the puny, weak-germinating, and very slow-growing hybrid pear. Some combinations germinate nearly 100 per cent and a large per cent survive in the plant bed and in the nursery row. Other crosses suffer from 50 to 75 per cent loss. Since certain parents give a low survival, the writer suggests that the cause is probably genetic. Perhaps such weak individuals would have been of little value.

Reimer (2) and others have mentioned the problems of fire blight inoculation in pears. The writer has used a "budding technique" in managing this operation. Such a disease transfer is slow and laborious but very efficient. It has its limitations, but does a good job of sorting out the susceptible plants in the nursery row.

Large seedling populations, selection testing, and replicated plots in orchard trials take up considerable acreage under the best of management. Our seedling strawberries have usually been set 4 feet x 4 feet and evaluated from the hill. Red raspberry seedlings have usually been set 4 feet x 3 feet and evaluated from single plants. Pear seedlings have been sorted for fire-blight resistance in the nursery row and these selections moved to the orchard, four trees being set in one hole and the groups 20 feet x 20 feet. Larger-scale trials use three or more replications; berry plots, single row 30¼ feet long; pear plots of three trees, normal orchard spacing.

Tasting thousands of seedlings does not appear to be a serious problem to the layman. The strawberry ripening season is short. Most of the red raspberry tasting occurred during a 6-weeks period each year, and note taking on pear fruits can be spread out over three months or more. A small amount of baking soda taken with water half way between meals will neutralize acidity developed in tasting, but does not correct other digestive disturbances. Perhaps a good plan is to employ young people such as senior college students to make preliminary notes on quality and flavor. Then the breeder can check on this work and take some additional notes on the more important selections.

Tests made by selected growers are very useful, but sometimes disappointing. Records taken by very busy growers are usually limited. Some hesitate to express opinions because they may be quoted. Others lose labels and records only to discover something valuable later. However, careful selection of growers reduces many of these troubles, and some grower tests are essential.

Methods of introducing new varieties developed in breeding work, usually are matters of policy of the organization with which the research worker is connected. Most experiment stations have adopted

some method of control over such varieties. Releasing new material to the public without any control may appear generous but most workers find it impractical and wasteful. Grower organizations often sponsor new varieties and prevent abuses. Some workers build up a considerable supply of nursery plants before releasing a new variety. Then a large number of growers can be supplied at one time. The writer follows the practice of securing plant patents on new varieties and licensing farmers to grow and sell plants. The small royalty charge covers the cost of patenting and corresponds to the membership fee in a grower organization. There probably are objections to any method of control, but most of these can be eliminated or reduced by careful management. Government-employed research workers usually are financed by taxpayers' money, and hence are under obligation to make the results of their labor available to *all the people* on a *reasonable basis*. The writer considers that it is impractical to make this a free basis.

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Inheritance of Pollen Sterility in Some Peach Varieties

By D. H. Scott, *Cheyenne Horticultural Field Station, Cheyenne, Wyo.,* J. H. Weinberger, *U. S. Horticultural Field Laboratory, Fort Valley, Ga.*

Most commercial peach varieties are perfect-flowered and self-fertile. Pollen sterility is a factor of commercial importance with only a few varieties, such as J. H. Hale or Halberta. Set of fruit on such varieties when planted in blocks is often poor, since conditions for insect activity are frequently bad during the early peach-blooming season. Also there is advantage in setting peach varieties in solid blocks. Consequently new varieties developed by breeding should preferably be perfect-flowered and self-fruitful. Each peach seedling occupies considerable ground space for a number of years, therefore, the presence of pollen-sterile seedlings in the breeding plots is costly. A knowledge of the pollen condition of varieties used as parents, therefore, should be helpful in planning an efficient peach breeding program.

In the peach breeding work at the Plant Industry Station, Beltsville, and at the U. S. Horticultural Field Laboratory, Fort Valley, Georgia, individual seedling records have been kept for all the progenies. One of the characters noted was the presence of pollen (pollen-fertile) or its absence (pollen-sterile) in the anthers of seedling flowers. In conducting the work many varieties have been selfed and a large number of crosses have been made between different varieties some of which had been selfed and some had not been selfed. The work reported here is based on the examination of flowers from approximately 9,000 seedlings.

Blake and Connors (1) have reported that pollen sterility in peaches is probably a simple recessive, the condition apparently controlled by a single pair of genes. This was found to be true in the work reported here (Tables I and II) except in Plant Introduction variety No. 101676 which will be discussed later. The principal purpose of this paper is to classfy peach varieties according to their pollen condition, based on progeny performance in crosses or selfs as shown in Tables I, II, III, and IV. Three classes of varieties are listed: those that are fertile homozygous dominants, heterozygous varieties that have fertile pollen, and homozygous recessives that are pollen-sterile. The last class can be determined by examining the flowers of the variety, but the others can be determined only from their progeny behavior in selfed or crossed lines. For the sake of brevity, only two or three progenies are reported for a homozygous parent variety which yielded the same results when used in two or more crosses. For instance, Rochester has a homozygous dominant pollen condition which was evidenced in 11 crosses, but only two progenies are listed to illustrate Rochester parentage. Likewise, varieties that were selfed and found to be homozygous dominants are not listed in the tables involving crosses. On the other hand, varieties known to be in a heterozygous condition or to be homozygous recessives are included

in the tables of crosses since they indicate the condition of the variety with which they are crossed.

Selfing was accomplished by covering large limbs with fine-mesh cheese cloth bags before any flowers had opened. The bags were left on the branches until after the petals had fallen. Crosses were usually made on trees under cheesecloth cages. Occasionally some flowers were crossed on individual limbs and the limbs covered with cheesecloth as in the selfs. In making crosses, emasculation was done at an early stage before any of the anthers had dehisced.

The heterozygous pollen-fertile varieties, or those containing the recessive gene as well as the dominant, are shown in Tables I and II. The selfed varieties are listed in Table I and the cross-pollinated varieties in Table II. In Table II the crosses are separated into 2 categories. The first part of the table shows Chinese Cling, Halberta,

TABLE I—Peach Varieties Heterozygous for Pollen Fertility as Indicated by Progenies from Self-fertilization

Variety Selfed	No. of Pollen-Fertile Seedlings	No. of Pollen-Sterile Seedlings
Belle	70	25
Canadian Queen	93	27
Cumberland	118	29
Eureka	47	19
Fair Beauty	62	14
Fay Elberta	17	4
Fireglow	43	15
Golden Globe	11	6
Halehaven	30	7
July Elberta	161	42
South Haven	33	15
St. John	20	3
Valiant	35	12
Vedette	18	8
Veteran	92	31
Viceroy	96	35
White Hale	24	9
Observed	970	301
Calculated, 3:1 ratio	953.3	317.7
$X^2 = 1.07$; $P = 30\%$		

and J. H. Hale crossed with a number of varieties. These three varieties are homozygous recessives and, consequently, when crossed with a heterozygous parent the progeny segregation approaches a 1 : 1 ratio for pollen sterility. The X^2 value of 2.42 does not exceed the 5 per cent point for 1 degree of freedom so that the segregation of 470 fertile to 519 sterile seedlings from all the crosses falls within the limits of chance. The second part of Table II shows the pollen-fertile varieties which, when crossed, produced progenies that segregated for pollen condition in approximately a 3 : 1 ratio, which indicates that both parents are heterozygous. The X^2 value of 0.05 indicates an unusually close fit to the theoretical 3 : 1 segregation.

By combining the varieties listed in Tables I and II it can be seen that the following ones of those investigated are heterozygous for pollen fertility: Belle, Canadian Queen, Cumberland, Early Wheeler (Red Bird), Elberta, Eureka, Fair Beauty, Fay Elberta, Fireglow, Golden Globe, Halehaven, July Elberta, Marigold, Mark Late, South Haven, St. John, Valiant, Vedette, Veteran, Viceroy, White Hale. Since

TABLE II—PEACH CROSSES WITH SEEDLINGS SEGREGATING FOR POLLEN FERTILITY OR STERILITY

Cross	No. of Pollen-Fertile Seedlings	No. of Pollen-Sterile Seedlings
Crosses with Approximately 1:1 Segregation		
Chinese Cling × Canadian Queen	50	32
Chinese Cling × Halehaven	100	100
Chinese Cling × July Elberta	66	92
Chinese Cling × Marigold	45	65
Chinese Cling × Mark Late	61	62
Chinese Cling × Vedette	58	79
Halberta × Fay Elberta	2	2
Halberta × Golden Globe	7	4
Halberta × Halehaven	23	13
Halberta × Marigold	4	6
Halberta × White Hale	7	5
J. H. Hale × Belle	47	59
Observed	470	519
Calculated, 1:1 ratio	494.5	494.5
$X^2 = 2.42$; P = 14 per cent		
Crosses with Approximately 3:1 Segregation		
Fair Beauty × Marigold	8	3
Belle × Fireglow	30	5
Golden Jubilee × Marigold	53	14
Golden Jubilee × Early Wheeler	13	4
Halehaven × Fair Beauty	42	14
Halehaven × Fay Elberta	4	3
Halehaven × Early Wheeler	8	4
Halehaven × White Hale	19	8
Mark Late × Cumberland	6	5
Mark Late × Elberta	13	4
Mark Late × Salberta	9	4
Veteran × Canadian Queen	14	4
Veteran × Fair Beauty	22	6
Veteran × Fireglow	8	9
Veteran × Mark Late	13	4
Veteran × Early Wheeler	4	1
Observed	266	92
Calculated, 3:1 ratio	268.5	89.5
$X^2 = 0.046$, P = 90 per cent		

Chinese Cling, Halberta, and J. H. Hale are homozygous recessives, any pollen-fertile seedlings resulting from crosses involving any one of these three as a parent will have a heterozygous pollen condition.

Table III shows the varieties that are pure dominants with respect to pollen fertility as shown by selfed progenies which yielded no pollen-sterile seedlings. In Table IV are listed crosses between one variety known to contain the recessive gene for pollen fertility, as shown in Table I or II, and a variety of previously unknown genotype. Since there was no segregation for pollen sterility in these crosses, one parent was homozygous dominant and has been indicated as such in column three of the table. By combining the information in Tables III and IV it is seen that the following varieties of those studied possess the homozygous dominant genes for pollen fertility: Admiral Dewey, Admiral Dewey x St. John seedling, Chili, Dixigold, Early Elberta, Early Hiley, Eclipse, Gold Drop, Goldeneast, Hiley, Illinois, Kalamazoo, Leeton, Lemon Free, Marquette, Maxine, Muir, Newcomb, Ontario x Arp seedling, Oriole, Pallas, Quetta (nectarine), Rochester, Sunbeam, USV No. 8 (Hiley seedling).

A variety known as Plant Introduction No. 101676 has been of interest as mentioned previously on the first page, because when it

TABLE III—HOMOZYGOUS POLLEN-FERTILE PEACH VARIETIES AS INDICATED BY NON-SEGREGATING PROGENIES FROM SELF-FERTILIZATION

Variety Selfed	No. of Pollen-Fertile Seedlings	Variety Selfed	No. of Pollen-Fertile Seedlings
Admiral Dewey × St. John Seedling	57	Lemon Free	26
Chili	94	Marquette	97
Eclipse	130	Maxine	76
Gold Drop	194	Newcomb	12
Goldeneast	39	Ontario × Arp seedling	88
Hiley	12	Pallas	101
Illinois	106	Rochester	140
Kalamazoo	22		

TABLE IV—PEACH CROSSES IN WHICH ONE PARENT IS HETEROZYGOUS AND THE SEEDLINGS ARE ALL POLLEN-FERTILE

Cross	No. of Seedlings	Variety Indicated As Homozygous Dominant*
Chili × White Hale	24	Chili
Cumberland × Sunbeam	7	Sunbeam
Golden Jubilee × Sunbeam	20	Sunbeam
Halberta × Eclipse	35	Eclipse
Halberta × Oriole	13	Oriole
J. H. Hale × Dixigold	337	Dixigold
J. H. Hale × Early Elberta	75	Early Elberta
J. H. Hale × Early Hiley	58	Early Hiley
J. H. Hale × USV No. 8	202	USV No. 8
Halehaven × Admiral Dewey	8	Admiral Dewey
Halehaven × Dixigold	31	Dixigold
Halehaven × Early Hiley	24	Early Hiley
Halehaven × Oriole	24	Oriole
Halehaven × Sunbeam	14	Sunbeam
Hiley × Fireglow	153	Hiley
Hiley × Halehaven	35	Hiley
Hiley × July Elberta	17	Hiley
Leeton × Halehaven	7	Leeton
Leeton × White Hale	7	Leeton
Maxine × July Elberta	47	Maxine
Muir × Halehaven	11	Muir
Pallas × Fireglow	20	Pallas
Pallas × Halehaven	13	Pallas
Pallas × July Elberta	25	Pallas
Quetta** × Fireglow	15	Quetta
Quetta** × Halehaven	28	Quetta
Quetta** × Valiant	3	Quetta
Rochester × Fireglow	135	Rochester
Rochester × White Hale	108	Rochester
USV No. 8 × Fair Beauty	117	USV No. 8
USV No. 8 × Fireglow	224	USV No. 8
Veteran × Oriole	10	Oriole
Veteran × Sunbeam	24	Sunbeam

*By comparison with findings in Tables 1 and 2.
**A nectarine

has been used as a parent in crosses all the seedlings have been pollen-sterile. The variety has been crossed with Fay Elberta, Valiant, Vedette, Fireglow, and Canadian Queen, the crosses producing 22 seedlings. The anthers of these seedlings have a pink or white color in contrast to the light yellow color of pollen sterile anthers as found in J. H. Hale. The blossoms appear to be normal in other respects and the flowers set fruits well under open pollination. Sufficient time has not elapsed to make a genetic study of this pollen condition.

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Characteristics of the Progeny of Certain Peach Varieties

By J. H. WEINBERGER, *U. S. Horticultural Field Laboratory, Fort Valley, Ga.*

THERE is need for new and improved varieties of peaches, and in recent years there has been a great deal of interest in the breeding of new sorts. Peach breeding has been in progress at the U. S. Horticultural Field Laboratory, Fort Valley, Georgia, since 1937, with the planting of seedlings resulting from crosses made the previous year at the Plant Industry Station, Beltsville, Maryland. Records on tree behavior and fruit characters of approximately 5500 seedlings of known parentage were made in the period 1939–43. Information on some of the genetic characters of a number of peach varieties was obtained. To make some of this information available to others interested in peach breeding, a summary of the progeny behavior of 23 crosses and 4 selfs having relatively large populations is presented here.

In making cross pollinations all flowers in a cheesecloth bag or under a cheesecloth cage were emasculated before the anthers had dehisced. Collected pollen was applied to the stigmas with a small brush. Since the cheesecloth provided protection from frost, it was usually allowed to remain until danger of frost was past. J. H. Hale flowers, being pollen-sterile, were not emasculated. In selfing, individual limbs or whole trees were enclosed in cheesecloth before any of the flowers had opened.

After harvest, seeds of early-ripening female parents were planted on sterile media, following the method developed by Tukey (4). They were then placed in a refrigerator for after-ripening. Rapidly developing embryos were removed from the refrigerator at periodic examinations, and remaining slow-growing embryos were given no more than 2 months of cold treatment. Using this method at Fort Valley, trees 1 to 3 feet tall were obtained the same season the pollinations were made. Seeds of late-ripening female parents were after-ripened in the usual way, and germinated in a greenhouse. The seedlings were planted in position in the field in early spring. The spacing finally adopted placed the seedlings at 4-foot intervals in rows 12 feet apart.

Fruiting was obtained the third growing season in the field, and the fruit data in Table I are based on the seedling behavior in that year. A low percentage of the seedlings failed to bear fruit the third year, but very few seedlings failed to set flower buds the second year. A severe roguing the third summer prevented the close spacing of seedlings in the field from becoming a serious handicap.

Blossom Type:—The blossoms were grouped into two classes, the large-petaled or showy type, and the medium- and small-petaled or non-showy type. Attempts to divide the latter class into medium and small types were not always successful. Bailey and French (1) have recently shown that the non-showy type is dominant and the showy type is recessive, and inheritance is controlled by a single pair of

TABLE I—FLOWERS, BUD, AND FRUIT CHARACTERS OF PEACH VARIETY PROGENIES EXPRESSED IN PERCENTAGES

Parentage	Number of Seedlings	Type of Bloom		Time of Bloom			Bud Set			Time of Ripening (Weeks Earlier Than Elberta)									Fruit Size (Inches)			
		Non-Showy	Showy	Early	Medium	Late	Light	Medium	Heavy	7	6	5	4	3	2	1	0	−1	1¾ to 2	2 to 2¼	2¼ to 2½	2½ to 3
Cumberland self	38	2	98	0	94	6	17	73	10	5	8	26	11	13	18	16	3	0	14	31	41	14
(Ad. Dewey × St. John) × Ad. Dewey*	84	0	100	93	7	0	4	64	32	0	24	14	37	2	21	2	0	0	2	51	39	8
(Ad. Dewey × St. John) × Halehaven	94	51	49	94	6	0	15	74	11	2	8	15	19	7	30	7	8	4	0	40	43	17
(Ad. Dewey × St. John) × Oriole	110	63	37	58	41	1	26	40	34	4	11	17	22	16	18	4	8	0	6	65	28	1
(Ad. Dewey × St. John) × Early Wheeler**	50	0	100	67	31	2	0	37	63	14	29	25	6	14	12	0	0	0	0	16	50	34
(Ad. Dewey × St. John) × South Haven	75	53	47	83	17	0	6	75	19	0	4	19	17	15	27	7	8	3	1	51	45	3
(Ad. Dewey × St. John) × Veteran	119	2	98	32	66	2	31	57	12	0	5	8	20	10	28	5	16	8	3	74	20	3
Halehaven × Fair Beauty	51	74	26	5	59	36	36	57	7	0	0	14	10	15	29	16	8	8	2	29	49	20
Halehaven self	270	74	26	88	11	1	27	49	24	3	10	15	22	18	16	4	9	3	3	39	51	7
Hiley × FV 9-60†	114	52	48	97	3	0	53	46	1	0	0	18	49	30	3	0	0	0	3	53	40	4
Hiley × Early Rose	30	0	100	0	29	71	0	45	55	0	0	0	37	33	30	0	0	0	13	70	17	0
Hiley × Fair Beauty	85	45	55	12	87	1	24	72	4	0	0	7	17	24	29	22	1	0	5	73	18	4
Hiley × Fireglow	152	0	100	49	51	0	14	69	17	0	0	8	11	16	28	23	13	1	1	20	62	17
Hiley × Halehaven	34	40	60	3	83	14	26	66	8	0	0	0	3	26	32	24	15	0	6	29	53	12
Hiley × Sunbeam	99	49	51	67	33	0	40	59	1	0	0	10	26	17	21	23	3	0	8	70	21	1
J. H. Hale × Dixigold	307	48	52	62	38	0	18	77	5	0	0	0	0	0	1	59	38	2	0	18	66	16
J. H. Hale × Early Elberta	60	48	52	55	45	0	73	27	0	0	0	0	0	0	0	14	48	38	0	8	57	35
J. H. Hale × Early Hiley	48	53	47	82	18	0	30	70	0	0	0	0	0	0	6	44	44	6	0	15	50	35
J. H. Hale × Belle	88	75	25	49	50	1	47	53	0	0	0	0	0	1	0	28	58	13	0	30	60	10
July Elberta self	115	72	28	46	54	0	48	52	0	0	3	10	10	14	26	16	12	9	7	57	33	3
Maxine × Hiley	46	0	100	0	73	27	6	67	27	0	0	0	2	24	24	23	27	0	0	33	67	0
Muir × Hiley	30	100	0	3	90	7	33	61	6	0	0	0	0	0	3	94	3	0	3	64	33	0
Rochester × (Ad. Dewey × St. John)	63	2	98	72	28	0	3	54	43	0	12	8	26	8	32	10	4	0	3	34	53	10
Rochester × Halehaven	37	33	67	84	16	0	32	46	22	5	8	5	30	30	14	3	5	0	0	62	38	0
Rochester × Valiant	35	47	53	64	36	0	3	19	78	0	9	6	17	23	14	6	25	0	3	74	23	0
Rochester × Veteran	52	0	100	23	75	2	4	45	51	0	6	21	19	12	19	6	17	0	6	63	29	2
Veteran self	45	0	100	0	23	77	28	66	6	0	0	7	11	11	13	21	28	9	2	20	64	14

*Admiral Dewey.
**Early Wheeler (Red Bird).
†(Admiral Dewey × St. John) × Halehaven.

TABLE I—*(Continued)*

Parentage	Fruit Form		Pubescence			Red Skin Color			Flesh Color		Firmness			Adhesion			Quality			
	Round	Ovate	Light	Medium	Heavy	0 to 4	5 to 7	8 to 10	Yellow	White	Soft	Medium	Firm	Free	Semi-Cling	Cling	Poor	Fair	Good	Excel-lent
Cumberland self.	16	84	48	52	0	74	20	6	29	71	53	44	3	66	5	29	8	24	57	11
(Ad. Dewey × St. John) × Ad. Dewey*	80	20	0	43	57	9	19	72	100	0	37	44	19	56	12	32	0	29	58	13
(Ad. Dewey × St. John) × Halehaven	86	14	2	81	17	27	42	31	99	1	15	58	27	74	3	23	2	39	47	12
(Ad. Dewey × St. John) × Oriole.	61	39	5	90	5	25	55	20	100	0	23	60	17	61	5	34	5	13	74	8
(Ad. Dewey × St. John) × Early Wheeler**	74	26	70	17	13	18	62	20	2	98	61	25	14	4	6	90	4	48	46	2
(Ad. Dewey × St. John) × South Haven	63	37	4	73	23	33	45	22	99	1	30	47	23	69	9	22	4	35	60	1
(Ad. Dewey × St. John) × Veteran	68	32	6	80	14	41	42	17	100	0	30	42	28	56	9	35	6	38	50	6
Halehaven × Fair Beauty	64	36	60	40	0	39	47	14	100	0	4	77	19	86	12	2	0	45	53	2
Halehaven Self	85	15	9	88	3	19	43	38	96	4	5	61	34	61	11	28	7	22	63	8
Hiley × FV 9-60†	68	32	87	13	0	50	34	16	39	61	4	68	28	100	0	0	1	49	49	1
Hiley × Early Rose	40	60	7	93	0	23	67	10	0	100	20	53	27	47	0	53	10	50	40	0
Hiley × Fair Beauty	39	61	87	13	0	67	28	5	40	60	6	83	11	76	1	23	7	64	28	1
Hiley × Fireglow	66	34	86	14	0	46	44	10	42	58	3	83	14	95	2	3	7	58	35	0
Hiley × Halehaven	76	24	53	47	0	38	50	12	53	47	9	85	6	100	0	0	3	21	73	3
Hiley × Sunbeam	51	49	88	12	0	59	36	5	39	61	6	86	8	94	2	4	5	49	46	0
J. H. Hale × Dixigold.	79	21	96	4	0	72	28	0	99	1	1	88	11	100	0	0	8	61	31	0
J. H. Hale × Early Elberta	85	15	97	3	0	82	18	0	98	2	0	86	14	83	0	17	13	70	17	0
J. H. Hale × Early Hiley.	77	23	98	2	0	71	29	0	46	54	4	81	15	65	0	35	6	48	46	0
J. H. Hale × Belle.	71	29	99	1	0	82	18	0	48	52	2	88	10	78	0	22	7	61	32	0
July Elberta self	70	30	78	21	1	41	36	23	100	0	2	77	21	87	10	3	3	57	37	3
Maxine × Hiley	87	13	19	76	5	43	55	2	50	50	22	63	15	76	2	22	2	15	81	2
Muir × Hiley	70	30	13	87	0	50	50	0	47	53	13	87	0	100	0	0	7	27	63	3
Rochester × (Ad. Dewey × St. John)	74	26	2	51	47	10	43	47	100	0	20	70	10	65	12	23	0	11	82	7
Rochester × Halehaven	92	8	0	81	19	5	30	65	100	0	32	24	44	65	11	24	0	14	78	8
Rochester × Valiant	80	20	6	77	17	40	40	20	97	3	14	66	20	77	9	14	3	20	68	9
Rochester × Veteran	85	15	8	67	25	31	37	32	100	0	39	39	22	67	8	25	0	8	73	19
Veteran self	87	13	27	71	2	60	36	4	100	0	24	62	14	36	2	62	4	20	76	0

*Admiral Dewey.
**Early Wheeler (Red Bird).
†(Admiral Dewey × St. John) × Halehaven.

genes. The ratios expected on this basis were closely approximated in the present results. Halehaven, South Haven, Fair Beauty, Sunbeam, and J. H. Hale have non-showy blossoms and are heterozygous, since they gave a 1 : 1 ratio when crossed with a homozygous recessive. Belle crossed with J. H. Hale, and July Elberta selfed, gave a 3 : 1 ratio, indicating these varieties are heterozygous dominants also. Muir crossed with Hiley, a showy recessive, resulted in 100 per cent non-showy progeny. Muir is therefore homozygous for non-showy character.

Time of Blossoming:—In breeding peaches for extreme southern areas, time of blossoming is important for it reflects the chilling requirement of a variety to break its rest period. Varieties with a long chilling requirement, like Early Rose, invariably blossom later than other varieties at Fort Valley, and following warm winters they suffer from delayed foliation. The Hiley variety blossoms early and requires a minimum of chilling among important commercial varieties. As shown in Table I, the time of blossoming of the progeny was influenced by parental type, but considerable variation occurred. The late-blossoming influence of Fair Beauty, Early Rose, Maxine, and Veteran parentage, all varieties having a long chilling requirement, can be noted. Halehaven progeny tended to blossom early, and some of these seedlings required less chilling to break their rest period than did the Hiley variety.

Bud Set:—Bud set is important in a commercial variety, since a heavy bud set indicates ability to produce ample flower buds under unfavorable conditions or while bearing heavy crops. While progeny behavior in this character was influenced by parental type, some notable exceptions occurred. Cumberland, a variety with a heavy bud set, when selfed, produced offspring 73 per cent of which had a medium bud set. On the other hand 78 per cent of the progeny of Rochester x Valiant, two varieties with medium bud set, had a heavy bud set. Early Wheeler often has a light set of buds, but when crossed with an Admiral Dewey x St. John seedling, its offspring had an unusually heavy bud set.

Time of Fruit Ripening:—Since the data cover five seasons, it is impracticable to present actual ripening dates. The time of ripening of the seedlings is given in Table I as the number of weeks they were earlier or later than Elberta in ripening. Some varieties, as Muir, Hiley, Dixigold, and Early Rose, when crossed with other varieties, produced offspring which had a relatively narrow spread in time of ripening. The progeny of other varieties such as Halehaven and July Elberta ripened over a much longer period. Halehaven selfs, actually the F_2 generation of J. H. Hale x South Haven, ripened from Mayflower season through and past Elberta season. Since very early-ripening varieties cannot be used as female parents, it is important in breeding early peaches to select as parents varieties which are heterozygous for this character.

Size of Fruit:—Size of peaches will vary from season to season, but in the period 1939–1943 no serious drouth interfered with fruit growth to affect comparisons. J. H. Hale progeny tended to bear

large fruit, while Hiley offspring generally had smaller-sized fruit. Early Wheeler was a valuable parent in this respect, for although its progeny ripened very early they produced large-sized peaches also. The desirability of using large-fruited parents in breeding peaches is evident.

Fruit Form:—Fruits were classified as round or ovate, although many varied forms were found also. Eighty-four per cent of Cumberland selfs were ovate, while 87 and 85 per cent respectively of Veteran selfs and Halehaven selfs were round. The oval form has been described as dominant over round form (2), but in the progenies listed in Table I the round form predominates.

Pubescence:—All gradations in amounts of pubescence were found, but seedlings were classified as having light pubescence as in J. H. Hale or Hiley; medium pubescence as in Belle or South Haven; and heavy pubescence as in Admiral Dewey and Rochester. The offspring tended to resemble the parents in this character. Eighty-eight per cent of Halehaven selfed progeny had medium pubescence, while approximately half of Hiley x Halehaven hybrids had light pubescence and half had heavy pubescence. None of the Rochester x Halehaven crosses had light pubescence, though only 19 per cent had heavy pubescence. These data do not indicate that heavy pubescence is dominant over light pubescence, as previously suggested (2).

Red Skin Color:—Fruit color was classified from 0 to 10 on the basis of 10 representing complete coverage. A rating of 5 or more is considered satisfactory, but complete coverage is not desirable. Highly colored varieties like Rochester and Admiral Dewey transmitted this character to their progeny, while J. H. Hale and Hiley offspring often lacked a satisfactory red color.

Flesh Color:—Connors (3) has shown that white flesh is dominant over yellow in peaches, and that a single gene controls inheritance. Cumberland, Belle, Hiley and Early Hiley, all white varieties, are heterozygous for white flesh color. Early Wheeler and Early Rose are homozygous whites. Yellow-fleshed varieties are, of course, homozygous recessives.

Firmness:—All degrees of firmness of flesh at maturity occurred, including a few non-melting types in Early Wheeler and in Veteran progenies. In a cross Early Wheeler produced 61 per cent soft-fleshed seedlings, and Cumberland, when selfed, 53 per cent. Early Rose, a non-melting type like Early Wheeler, when crossed with Hiley produced 20 per cent soft-fleshed seedlings and 27 per cent firm-fleshed. J. H. Hale has a firm flesh, and few of its progeny were soft-fleshed; but on the other hand, few were firm-fleshed. One of the characteristics not indicated in these data is the soft apex of the fruit. This character in the Hiley variety was inherited by all Hiley offspring.

Adhesion:—Tendency of peach flesh to cling to the pit is a variable character difficult to classify. At one extreme is the air-free type and at the other extreme is the kind that shows no tendency toward separation, as Early Wheeler or Early Rose. In between are all gradations of adhesion, which are affected by maturity of the peach and firmness

of the flesh particularly. In a given variety the degree of adhesion may vary from year to year.

Within a progeny the very-early-ripening seedlings tended to cling more than the late-ripening seedlings, indicating that the length of the development period of the fruit affects display of this character. For example, in the July Elberta self population more than half of the earliest 23 per cent of the progeny to ripen were cling or semi-cling, while only 1 per cent of the later-ripening 77 per cent tended to cling. It is believed that the classification in Table I of many of the offspring of Rochester, Admiral Dewey x St. John, and Halehaven as cling or semi-cling was too severe the first season, and a number of them should be considered of the free type. For instance, the seedling FV 9–60 was classified as cling, for the flesh separates from the pit with difficulty and only when the fruit is very ripe. However, according to its progeny behavior in crosses with Hiley, FV 9–60 seems not to carry factors for clingstone. Hiley in other crosses was heterozygous for freestone, so FV 9–60 must be homozygous for freestone or else segregation in the progeny should have occurred. It is probable that many early-ripening seedlings and varieties that are phenotypic clings are genotypic freestones.

Allowing for the influence of early-ripening on clingstone behavior, Fireglow, Dixigold, Halehaven, Cumberland, July Elberta, Muir, and Sunbeam carry strong factors for freestone. Hiley, Early Hiley, Early Elberta, Maxine, J. H. Hale, and Belle, all freestone varieties, and the semi-freestone varieties Fair Beauty and Veteran, carry factors for clingstone as well as freestone.

Edible Quality:—Four classes of seedlings as to fruit quality were made. Hiley and Elberta peaches are considered fair quality, the flavor being no credit to the variety but not too objectionable. Poor quality indicates an objectionable flavor. Rochester variety is considered excellent quality, and more than three-fourths of its progeny in crosses with other varieties were in the good and excellent classes. Halehaven, Oriole, Maxine, and Veteran likewise carry factors for good quality. Hiley and J. H. Hale progeny tended to be only fair in quality.

The heterozygous nature of the peach varieties is evident in these results. This probably explains the occasional appearance of fairly desirable seedlings from only mediocre parents. All but a few of the more promising seedlings obtained are descendants of the J. H. Hale variety.

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Temperature as a Factor in Breeding Peaches for a Mild Climate

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There are three ways in which temperature can affect the production of peaches when grown in a "mild" climate. These are (a) the degree of fulfillment of the chilling requirements, (b) the influence of high temperatures in the spring upon time of bloom and (c) the effect of extreme low temperatures (below 20 degrees F) after periods of warm weather resulting in injury to buds, flowers and fruit. From the standpoint of temperature alone, a peach variety to be fully adapted to such a climate must combine very moderate cold requirements with rather high heat requirements for blooming, as well as hardiness of bud and flower to avoid injury from late spells of cold weather. These will be considered separately.

Cold Requirements for Normal Development

A primary objective of the peach breeding work has been the production of early *commercial* varieties for areas having a large proportion of winters with comparatively little cold. For this reason Hiley, a commercial variety which combines moderate chilling needs with fair shipping quality, was crossed with Pallas and Smith, two varieties of the non-shipping Honey type needing little cold. Indian Free, which is fairly well adapted from this standpoint to central Texas, was crossed with the same two varieties. Other crosses include Florida Gem x Early Elberta and Triana x Belle.

In order to make selections for further crosses, all trees were given an adaptability rating with respect to their behavior after winters with the least cold. Each tree was first graded according to the proportion of leaf buds developing, the proportion of flower buds developing, set of fruit and yield. The adaptability scale is from 0 to 10, the former being least adapted, the latter best. Since factors other than cold may be expected to influence flowering and yield, a total of the points for leaf, flower and fruit development is not an adequate expression of relative adaptability to a mild winter. This adaptability rating, while based on these things, must necessarily take into consideration such factors as age of trees, differences in vigor of the seedling trees, and the possibility of diseases such as crown gall and oak root rot.

In order to illustrate their application, ratings for adaptability to mild winters assigned to several varieties are given: Babcock 8, Bestmay 7, Dr. Burton 3, Early Rose 7, Early Wheeler 0, Eclipse 6, Fair Beauty 3, Greensboro 7, Halehaven 6, Hiley 7, Honey 10, Indian Free 6, Japan Dwarf 7, J. H. Hale 2, Luttichau 10, Mamie Ross 6, Mayflower 1, Pallas 10, Rochester 5 and Smith 10. Such ratings can be added to ratings for other characters to give a useful total.

Adaptability ratings are given for the first generation seedlings of the commercial-Honey crosses and, for comparison, a small family of the cross Dr. Burton x J. H. Hale in Table I. The numerical

TABLE I—Ratings for Adaptability to Mild Winters

Parents and Cross	n	No. of Trees									
		1	2	3	4	5	6	7	8	9	10
Hiley	—	—	—	—	—	—	—	*	—	—	—
Pallas and Smith	—	—	—	—	—	—	—	—	—	—	*
Hiley × Pallas	8	—	—	—	—	—	—	—	4	3	1
Pallas × Hiley	40	—	—	—	—	—	7	12	13	8	—
Direct and reciprocal	48	—	—	—	—	—	7	12	17	11	1
Smith-Hiley	25	—	—	—	1	1	5	10	6	2	—
Hiley-"Honey"	73	—	—	—	1	1	12	22	23	13	1
Indian Free	—	—	—	—	—	—	*	—	—	—	—
Pallas and Smith	—	—	—	—	—	—	—	—	—	—	*
Pallas × Indian Free	16	—	—	—	—	4	3	5	1	3	—
Indian Free × Smith	8	—	—	1	0	1	4	0	0	2	—
Smith × Indian Free	6	—	—	—	—	—	1	0	0	3	2
Direct and reciprocal	14	—	—	1	0	1	5	0	0	5	2
Indian Free-"Honey"	30	—	—	1	0	5	8	5	1	8	2
Florida Gem × Early Elberta	17	—	—	—	—	1	4	2	6	4	—
Triana × Belle	23	—	—	—	2	2	3	5	5	5	1
Hiley-Honey	73	—	—	—	1	1	12	22	23	13	1
Indian Free-Honey	30	—	—	1	0	5	8	5	1	8	2
Total commercial-Honey	143	—	—	1	3	9	27	34	35	30	4
Dr. Burton	—	—	—	*	—	—	—	—	—	—	—
J. H. Hale	—	—	*	—	—	—	—	—	—	—	—
Dr. Burton × J. H. Hale	7	1	1	4	1	—	—	—	—	—	—

*Indicates status o the parent with respect to the progeny.

ratings appear as column headings. As the crosses were not made primarily to study the inheritance of this characteristic, differences between parents are not great. In crosses involving Hiley the largest frequencies are at 7 and 8 — between the two parents and within the range of the less well adapted parent. While numbers are small for crosses involving Indian Free, there is a tendency toward two modes at about the levels of the two parents. The Florida Gem and Triana crosses are rather widely scattered. There is evidence that Smith is more heterozygous than Pallas for factors affecting adaptability to mild winters. In both cases, a few segregates from crosses with Smith were less well adapted than seedlings involving Pallas as the Honey parent. The few trees from the cross of Dr. Burton x J. H. Hale when considered in connection with the other crosses indicate that the ratings are largely controlled by genetic factors, as all trees were grown in the same block.

While the results from the various commercial-Honey crosses are not strictly addable, the line in Table I giving this total does indicate what the breeder can expect in general from this type of cross. Trees with an adaptability rating of 8 or better are worth selecting from this standpoint. We thus have a total of 69 trees out of 143, or 48.3 per cent available for selection for other characters.

Heat Requirements for Blooming

Taken as a whole, varieties of peaches with moderate chilling requirements bloom early in the South, while varieties that need considerable cold bloom late. Among the first to bloom are Australian Saucer or Peento and Hall's Yellow, followed by varieties of the Honey group. The latest of the Honeys to bloom is Smith. Babcock

blooms between Honey and Smith. It is assumed that under otherwise normal conditions the annual variation in time of flowering is largely a response of the trees to temperature and is dependent upon their requirements for both cold and heat. It also seems reasonable that these factors play an important part in determining the relative blooming dates of varieties and seedlings. We are here interested in the distribution of the progeny of the commercial-Honey crosses with respect to date of full bloom when grouped according to their relative adaptability to a mild winter in the restricted sense used in this report.

In Table II the ratings for adaptability to mild winters have been placed in three groups: 2 to 4, 5 to 7 and 8 to 10, the last being the ones among which selections might be most profitably made. The average date of the last killing frost at College Station is March 9. All of the Honey varieties except Smith were in full bloom on or before this date in 1941, while the "commercial" varieties such as Indian Free came into full bloom after March 29. About half of the seedlings were in full bloom between March 20 and 24, which is intermediate between the parental blooming periods. More

TABLE II—Dates of Full Bloom of Trees, Grouped as to Adaptability (1941)

Adaptability Rating	Before Mar 10	Mar 10 to 14	Mar 15 to 19	Mar 20 to 24	Mar 25 to 29	After Mar 29	n
2 to 4	—	0	1	2	1	0	4
5 to 7	—	12	11	29	8	4	64
8 to 10	—	13	15	37	2	1	68
Hiley 7	—	—	—	—	*	—	—
Ind. Free 6	—	—	—	—	—	*	—
Pallas 10	*	—	—	—	—	—	—
Smith 10	—	—	*	—	—	—	—

*Indicates status of the parent with respect to the parent.

important to the breeder are two trees with an adaptability rating of 8 or better that were not in full bloom until March 25 and one additional tree with this high rating that was not in full bloom until after March 29. It is concluded that the requirements for heat and for cold are determined by distinct genes. It should then be possible to combine factors for adaptability to a mild climate and for considerable heat for blooming with factors for other desirable characteristics.

Hardiness

Hardiness of bud and blossom is of especial importance for varieties with moderate chilling requirements. This is because the milder winters sometimes provide both sufficient cold and heat to stimulate early development of the flower buds. When this occurs prior to a sudden drop in temperature the trees are caught in a condition in which they are highly susceptible to cold damage. This situation can be illustrated by a statement of conditions at College Station, Texas, during the spring of 1943. The accumulated hours at or below 45 degrees F were as follows: February 1—541, February 15—584, and March 1—626. The accumulated number of hours at or above 70 degrees on these dates was: February 1—57, February 15—93, and

March 1—124. Under these conditions the Honey variety, Luttichau, was in full bloom on February 18. Flower buds of nearly all of the commercial-Honey crosses showed some activity and a number of the trees were in full bloom by March 1. On March 3 the temperature dropped to 17 degrees F. The following two days were cloudy with a maximum of 78 degrees on the second day. The conditions provided a good test of hardiness of bud or flower as judged by the low yield of most trees.

As there may have been insufficient cold for normal production from seedlings with low or medium adaptability ratings, yield data are presented only for trees with an adaptability rating of 8 or more. This is the group of greatest interest to the breeder of varieties for a mild climate. These data are presented in Table III.

TABLE III—YIELDS OF SEEDLINGS ADAPTED TO MILD WINTERS AFTER A LOW OF 17 DEGREES F ON MARCH 3, 1943
(Pounds Per Tree)

Adaptability Rating	1 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100
8	10	5	5	4	1	0	1	1	0	0
9	1	10	5	3	4	2	2	1	0	1
10	0	2	0	0	1	0	0	0	0	0

There were 27 trees among the entire group of 143 commercial-Honey seedlings, considering all adaptability ratings, with a yield exceeding 30 pounds per tree. Twenty-one of these have an adaptability rating of 8 or more. Of the trees with an adaptability rating of 8, 26 per cent had over 30 pounds of fruit, while 43 per cent of the trees with a rating of 9 had this much fruit. There seems to be no indication that trees that need little cold are less well adapted from the standpoint of hardiness of bud or flower than those requiring more hours of chilling. The new combination of minimum chilling requirements, late bloom and cold hardiness of buds or flowers has thus been obtained in reasonable degree. For example, selection A 31–11 of the cross Pallas x Indian Free has an adaptability rating of 9, a bloom rating of 4 (full bloom between March 25 and 29, 1941) and a yield of 50 pounds in 1943. Another selection — A 26–18 Florida Gem x Early Elberta — while blooming 10 days earlier, equals A 31–11 in adaptability to mild winters, and exceeds it in hardiness of flower buds to cold. The yield of 100 pounds of fruit by A 26–18 in 1943 can be accounted for in part by vigor of tree as well as by other factors not discussed here.

Selections for further breeding have come from those trees combining adaptability to mild winters, medium to late blooming habit and hardiness of flower buds to cold. Other desirable characters which they have, while highly important in any introduction, must be given secondary consideration in breeding peaches for a mild climate.

Peach Breeding in Relation to Winter Chilling Requirement[1]

By J. W. Lesley, *University of California Citrus Experiment Station, Riverside, Calif.*

In regions having a mild winter climate, such as that occurring at moderate elevations in southern California, peach trees are subject to prolonged dormancy caused by insufficient winter chilling. The natural breaking of the rest period, which is marked by the renewal of growth, is normally brought about by a period of winter chilling, a certain minimum duration of chilling being required to induce normal growth.

Peach varieties differ widely in chilling requirement. Those that require little chilling are adapted to a subtropical climate like that of the coastal region of southern California. In the central valley of California and at the higher elevations in southern California, the amount of winter chilling is, as a rule, sufficient to break the rest period of standard varieties such as J. H. Hale and Rio Oso Gem. In parts of southern California where the winter climate is very mild, the amount of winter chilling frequently is not nearly enough for such varieties, and they regularly show symptoms of prolonged dormancy. At Riverside, California, for example, the peach crop has been adversely affected in 7 of the past 14 years. A slight deficiency of winter chilling is often beneficial (1), as it delays and prolongs the blooming period and so prevents a crop loss from spring frosts.

There are various methods of treating plants that have not received an adequate amount of chilling. Weinberger (4) reports that in the southern peach-growing part of Georgia, spraying with oil containing dinitro-o-cyclohexylphenol is promising as a method of compensating for insufficient winter chilling.

In recent years the hybridizing of certain commercial varieties of peaches with varieties introduced from South China, such as the Peento, which has saucer-shaped fruit, has resulted in the development of several promising new varieties having a rest period appropriate to the mild winter climate prevalent at the lower elevations in southern California. In this way the area suitable for peach growing has been extended. Presumably, the Chinese varieties having a short rest period originate from wild peaches native in subtropical regions of China where they receive little winter chilling. Since saucer fruit shape depends on a single dominant gene, according to Lesley (3), and since the seeds of such fruits seem to be low in viability, this is probably not a characteristic of wild peaches.

The present report is based on data obtained at the University of California Citrus Experiment Station during the past 17 years, in experiments on the breeding of peaches that require relatively little winter chilling. The chief agent in breaking the rest period was winter

[1]Paper No. 520, University of California Citrus Experiment Station, Riverside, Calif.

chilling; hence the "chilling requirement" here is a measure of the length of the rest period.

Experimental Procedure and Results

Delayed and irregular growth of the leaf buds is the most consistent outward symptom of insufficient chilling. The flower buds are similarly affected, but an extreme deficiency of chilling causes them to drop. The number of flowers is also much influenced by other, genetic causes: one seedling tree, for example, grew well in the breeding orchard for 10 years without blooming. The chilling requirement of the trees in the present studies was therefore estimated from the amount of growth of the leaf buds on shoots formed in the preceding season, and also from the condition of the buds on branches 2 years old, or older.

In the four seasons under consideration, namely, those of 1934, 1938, 1940, and 1943, when injury due to insufficient chilling was severe, seven grades were used. Grade 1 was assigned to a tree having the most advanced and even leafing, with no prolonged dormancy symptoms, and requiring the least chilling (Fig. 1, B); grade 7 was assigned to one showing the most severe symptoms, resulting in total crop failure, and requiring the most chilling (Fig. 1, A). Grading was done about April 9 of each year and was checked a few days later. Probably there was no sharp distinction between consecutive grades. In 1934 more than seven grades were distinguishable, whereas in other years, such as 1935, 1936, and 1941, only four or five grades were easily distinguishable, and in 1932 and 1942 even fewer. The data obtained in years when symptoms were not severe are not included in this report.

Comparisons of grades assigned to trees of the same varieties in different years indicate that the grades of 1934, 1940, and 1943 are in tolerable agreement, seldom differing by more than one grade. For example, comparison of the grades assigned the same 49 trees in 1940 and 1943 showed that 26 of these trees received the same grade both years, 21 showed a difference of one grade in the two years, and 2 trees showed a difference of two grades. The mean difference was one-half of a grade. Symptoms of insufficient chilling at Riverside, California, were much less severe in 1938 than in 1934, 1940, and 1943, and differences of one grade were more frequent in comparisons involving grades in 1938 and in any of the other years: Of 58 trees graded in 1938 and in 1940, 22 had the same grade both years, 23 differed by one grade in the two years, 12 by two grades, and 1 by three grades. The mean difference was eight-tenths of a grade. Of 17 trees graded in 1934 and in 1938, 5 received the same grade both years, while 12 differed by one grade. Young trees seem to require less chilling than older trees. As a rule, young trees, especially those 1 or 2 years old, were graded considerably lower than the same trees when 2 or more years older. This was not the case with trees recorded in 1940 and 1943, but the discrepancies in these years may have been due partly to differences in the relative amount of leaf growth in different years.

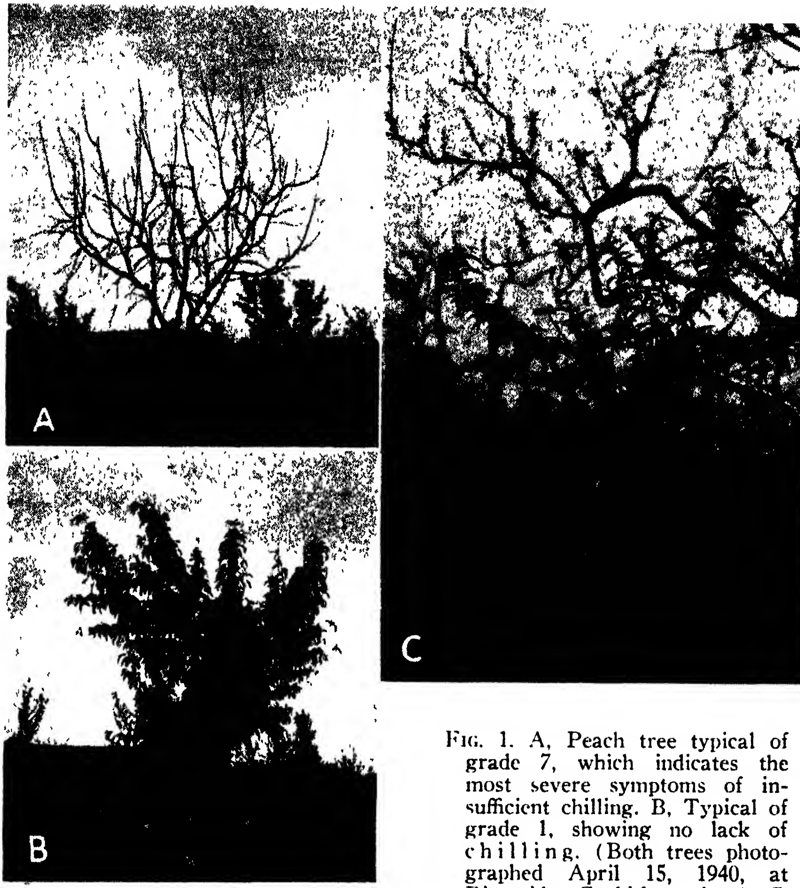

FIG. 1. A, Peach tree typical of grade 7, which indicates the most severe symptoms of insufficient chilling. B, Typical of grade 1, showing no lack of chilling. (Both trees photographed April 15, 1940, at Riverside, California.) C, Branch of Sims peach, with normal portion in bloom and bud-variant portion (in foreground) already in leaf. (Photographed April 23, 1943).

The chief defects of the method used in the present studies in estimating chilling requirement are the uncertainty of the amount of error and the difficulty of comparing data from different years. In practice it is rapid and, for the selection of improved varieties, it seems to be adequate. The Babcock variety has a chilling requirement somewhat less than that of grade 3, Lukens Honey is in grade 2, and J. H. Hale is in grade 6. Grade 3 indicates a chilling requirement not too great for the interior valleys of southern California, at the lower elevations; but for regions nearer the coast, which are not very subject to winter fog, grade 2 is preferable. A variety in grade 1 would be likely to suffer frost injury to the flowers, and especially to the young fruits, except in a very mild winter climate.

According to a method of estimation proposed by Lammerts (2), each variety is given an index number. This is the difference in days

between the deviation of the date of the beginning of leafing of the variety from that of Lukens Honey, in a year such as 1937, in southern California, when symptoms of insufficient chilling were at a minimum, and the corresponding deviation from Lukens Honey in the year to which the index number refers. The beginning of leafing is defined as the stage at which 1/8 to 1/4 inch of leaf growth has occurred on at least the terminal buds. Estimation of the beginning of leafing is probably more accurate than grading, and a better basis for comparison of the behavior of a variety in different years is provided. It necessitates observation of a variety in at least two seasons, of which one is a year of sufficient chilling, but it seems especially useful as a second test of chilling requirement, more precise than grading. A strictly quantitative method of measuring the effects of insufficient chilling is lacking. Leaf growth could be determined by measuring two or more samples of developing leaves on twigs of the last season's growth fully exposed to sunlight.

The data presented in Tables I and II were obtained from the grading of single trees of complete families, each family or progeny in Table I containing 19 or more plants. The trees were, as a rule, growing on their own roots. All the seedlings were obtained from controlled pollination and were usually grown for 1 year in the nursery before being planted in the orchard. The parent trees were selected as promising for the production of new varieties, and not for the genetic study of chilling requirement; they consisted of standard commercial varieties and, more often, of hybrids of known origin. The parents in the various crosses commonly differed considerably in chilling re-

TABLE I—CHILLING REQUIREMENT (CR)* OF PEACH PARENTS AND THEIR PROGENIES FROM CROSSING

Group and Series† Nos.	♀ Parent		♂ Parent		Number of Progeny Having Given Grade of Chilling Requirement						
	Variety	CR	Variety	CR	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7
Group 1											
51	B. I. 43135	4	BH 7	2+	–	10	24	–	–	–	–
186	89-3	6	Ramona	3	1	1	1	10	6	1	–
187	Hermosa	3	88-1	3	11	15	12	10	5	6	–
188	77-2	3	Ramona	3	–	10	9	1	1	–	–
189	141-4	5	Hermosa	3	2	4	5	2	4	2	–
190	Rosy	3	121-1	3	3	7	8	2	–	1	–
191	Rosy	3	11-5	2	3	10	9	3	4	1	–
193	11-5	2	Hermosa	3	4	8	4	4	1	–	–
218	Hermosa	3	71-2-5	2	24	29	7	–	–	–	–
227	71-2	4	97-1N-4	2	4	15	5	1	–	–	–
242	127-15	2	158-10	3	2	7	7	1	–	2	–
Group 2											
127	J. H. Hale	5	U. S. 39-19	2	–	3	5	6	4	1	–
128	J. H. Hale	5	18-6	2	–	2	9	5	2	1	–
165	46-3-3	2?	96-1	4	1	1	7	6	3	1	–
166	71-2	3	96-1	4	2	16	17	7	3	3	1
170	71-9	1	76-5	1?	3	12	4	1	–	–	–
172	Ramona	3	71-1	1	–	5	23	5	–	–	–

*The chilling requirement (CR) was estimated from stage of leaf development in early spring, CR 1 indicating least chilling requirement and early leafing, and CR 7 indicating greatest chilling requirement and late leafing.

†In the first series, parents and progeny were graded for chilling requirement in the same year (1940); in the next 10 series, parents were graded in 1940 and progeny in 1943; in the last 6 series, parents and progeny were graded in various other years.

TABLE II—Chilling Requirement (CR) of Peach Trees in Families Obtained from Selfing, CR 1 Indicating the Least and CR 7 the Greatest Chilling Requirement, Estimated from Amount of Leaf Development in Early Spring

Series	Origin	Parent		Progeny							
					Number Having Given Grade of Chilling Requirement						
		Generation	CR	Generation	CR 1	CR 2	CR 3	CR 4	CR 5	CR 6	CR 7
9–1	Lovell × BH 7	F_1	3	F_2	–	–	1	1	1	–	–
		F_2	3	F_3	1	–	–	–	–	–	–
		F_3	1	F_4	–	1	2	–	–	–	–
11–5	Elberta × BH 102	F_1	2	F_2	–	–	1	–	–	–	–
		F_2	3	F_3	–	1	–	–	–	–	–
		F_4	2	F_5	–	1	1	–	–	–	–
12–22	Elberta × Lukens Honey	F_1	2	F_2	–	1	3	–	–	–	–
		F_2	3	F_3	–	2	–	–	–	–	–
		F_3	2	F_4	–	1	2	–	–	–	–
		F_4	2	F_5	–	4	–	–	–	–	–
7–2	Peak × P. I. 32374	F_1	4	F_2	–	1	2	–	1	–	–
		F_2	3	F_3	–	–	–	1	–	–	–
		F_3	4	F_4	–	–	–	1	2	–	–
71–2	Early Imperial × 18–10	F_1	4	F_2	–	1	1	–	1	–	–
		F_2	2	F_3	3	–	–	–	–	–	–
31–1	J. H. Hale × Lukens Honey	F_1	3	F_2	–	1	4	–	–	–	–
		F_3	3	F_4	–	1	–	–	–	–	–
59–2	BH 27 × Early Elberta	F_1	1	F_2	–	–	–	1	–	–	–
		F_2	4	F_3	–	–	1	7	–	–	–
88–1	Early Crawford × 18–2	F_1	3	F_2	–	2	4	1	3	1	1
12–5	Elberta × Lukens Honey	F_1	3	F_2	–	3	2	2	2	–	–
55–1	Babcock × Early Elberta	F_1	3	F_2	–	–	5	2	–	1	–
44–2	Lovell × BH 107	F_1	2	F_2	1	1	2	1	1	–	–

quirement, but types requiring an extremely large amount of chilling were avoided.

The data in Table I are arranged in two groups. The first group, which is considered to be the more reliable of the two, consists of 11 series. The parents and progeny of series 51 were graded for chilling requirement in the same year (1940). The parents of the next 10 families in group 1 were graded in 1940, the progeny in 1943; and the records for any one variety in these two years agree well. The grades of the parents and progeny of the six series in group 2 were recorded in various years and are probably less reliable. A few of the progeny trees in Table I were graded in two different years. In these cases the grade assigned in the later year was chosen, as the orchard age was then nearer that of the parents at the time they were recorded, and the grades were therefore more comparable.

The occurrence of many grades of chilling requirement among peach varieties indicated at the outset that this character depended on multiple genes. The presence of six or seven phenotypes in a single progeny or family in Tables I and II points to the same conclusion.

Because of the limited number of grades and the small size of the families, the frequency distribution of single families can only be estimated very roughly. In most of the families in Table I several phenotypes occurred, in frequencies diminishing with increasing nearness to the extremes of the range. Such a distribution suggests the presence of multiple genes having a cumulative and more or less similar effect on the phenotype, and the absence of dominance.

In the six families in group 1 from parents both having the same grade or having a grade exactly intermediate between them, the number of offspring having a lower grade than either parent was greater than the number having a higher grade; but in three similar families in group 2, the opposite was the case. In both groups, where no grade exactly intermediate between the two parent grades occurred, a majority of the offspring were nearer in grade to the lower-grade parent.

The combined families in Table I, together with 16 smaller families not presented in the table, consisted of 773 trees. Among the 412 trees from parents both having the same grade or having a grade exactly intermediate between them, approximately equal numbers had the same grade as the parents, a lower grade, or a higher grade than the parents. Among the 361 trees from parents differing in grade but having no exactly intermediate grade, about two-thirds were nearer in grade to the lower-grade parent.

Transgressive variation occurred in many families, sometimes in both directions, as in series 189, 191, and 193. Of the 773 trees in families originating from crossing, 63 per cent had grades within the parental range, 21 per cent were lower and 16 per cent higher than either parent. The fact that the progenies were as a rule graded at a younger age and therefore tended to receive a lower grade than the parents may account for the slight excess, among the progeny, of trees with a lower grade than either parent.

Evidently some of the parents, if not all, were heterozygous. In hardly any case is simple dominance of low or high chilling indicated. Some series, such as 51 and 227, suggest the dominance of a gene or genes for low chilling; but others, such as series 172 and 188, suggest the dominance of high chilling. Both dominant and recessive genes may occur, or, more probably, the heterozygotes are intermediate.

Several small families obtained from selfing (Table II) also indicate that most of the parents were heterozygous. Of the 88 trees in these families, 24 per cent had a lower grade of chilling requirement than the parent, 36 per cent had the same grade as the parent, and 40 per cent had a higher grade. In the F_2 families of series 7–2, 71–2, and 88–1, in which parent and progeny were graded in the same year, some seedlings had less chilling requirement than the parent. These data indicate the existence of multiple genes for chilling requirement, which are partially dominant or perhaps intermediate.

Segregation is indicated in 5 of the 6 small F_3 and F_4 families and in one of the two F_5 families obtained by controlled self-pollination (Table II). Possibly the line originating from Elberta × Lukens Honey, now in F_5, is nearly homozygous. Theoretically, if it is assumed that there are two independent genes for chilling requirement, after three generations of selfing about three-fifths of the F_4 individuals should be homozygous. The larger proportion of heterozygous F_3, F_4, and F_5 families indicates that more than one gene difference is concerned in many of these crosses.

An attempt to determine the number of major genes affecting the rest period and other quantitative characters, their dominance rela-

tions and interaction, would require a series of homozygous lines. For this purpose, several inbred lines, some now in F_5 or F_6, differing in chilling requirement, time of maturity, texture of flesh, and other characters, have been developed.

After five or six generations of selfing, it may be possible by crossing such lines to breed a desired type merely by raising a few F_1 plants, and to thus avoid the present laborious method of raising large populations from highly heterozygous parents. These inbred lines may also be useful in physiological studies as a source of relatively uniform peach seedlings. After two to four generations of selfing, most of the lines show little or no loss of vigor, although undesirable recessive characteristics such as male sterility have been uncovered in some.

A peach tree discovered by Professor G. P. Weldon, of Chaffey Junior College, Ontario, California, has a single branch, apparently a bud variant, which regularly comes in leaf earlier than the rest (Fig. 1, C). If this difference is due to a single gene mutation, the phenotypic effect of this gene was very considerable and caused a reduction in chilling requirement of at least one grade.

Summary

Chilling requirement depends on multiple genes, of which some are probably intermediate. In a wild race homozygous for long-chilling genes, a mutant gene tending to reduce chilling requirement would be more favored by natural selection if the mutant type were intermediate than if it were recessive.

In breeding peaches adapted to a subtropical climate, the choice of parents will depend partly on what level of chilling requirement is most desirable. In the breeding work described in the present paper, crossing generally gave rise to a variety of phenotypes differing in chilling requirement. Apparently, nearly all parents were heterozygous, and the results of crossing varied widely. Most of the offspring were similar to the parents or were intermediate in chilling requirement, but transgressive variation occurred in both directions. About three-fifths of the combined F_1 families were within the parental range, one-fifth had less chilling requirement, and one-fifth had a greater chilling requirement than either parent.

From selfing, which in most cases was not associated with loss of vigor, out of 88 trees from several parents, 40 per cent appeared to have a chilling requirement greater than that of the parent, and about 24 per cent appeared to require less chilling. Selfing for three to four generations has led to the production of several lines, most of them vigorous and showing an increase in uniformity.

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A Comparison of the Effect of Colchicine Applications on Plants and Seeds

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Chromosome doubling by means of colchicine is an intriguing process to the plant breeder. Whether artificially produced polyploids will be of great economic importance remains to be determined. In the meantime the methods of using colchicine need more study. The layman has been led to believe that an application of some solution or ointment containing colchicine will act at once and with certainty. Even those who understand the actual process, by means of which colchicine acts, are by no means certain how frequently such doubled plants may be expected to occur nor do they know whether any particular species will react as do others.

The data contained in this paper were collected over a period of 4 years and are presented as a part of the great mass of such material now available. No attempt is made to review all literature to date. The methods used are not necessarily the most refined now available since improved techniques are constantly being developed and practical testing of these must come later.

Plant Treatment

Immersion Method:—This method consisted of the submergence of an actively growing tip of the plant in an aqueous solution of colchicine. General appearance and guard cell measurements were used to distinguish polyploids.

Very small seedlings such as blueberry were treated by the immersion of the growing tip only in a Petri dish while keeping the roots moist with tap water between damp filter papers outside the edge thus providing a treatment similar to that described by Thompson (3). This is to avoid the characteristic inhibition of root growth resulting when seeds are immersed. (Fig. 1.)

Solutions in Agar:—The concentrations of colchicine used in all tests were either 0.5 or 1.0 per cent in a 0.8 per cent agar solution. Colchicine was added to the agar while it was warm and in the fluid state. The method of using this mixture was application in the fluid state to the growing points, the solution hardened and sloughed off as the plants grew.

Injection Method:—This method was employed in a few instances by Myers (2) in his colchicine studies with perennial rye grass. In using this a glass tube was drawn out to a fine point and a rubber bulb was attached to the large end, making a very slender eye dropper. Before injection a similar fine pointed glass tube was forced into the onion bulb or growing point of the calla rhizome in a downward direction toward the center or growing point, thus removing a core and allowing the eye dropper to be forced into the vicinity of the growing point without clogging. Colchicine in concentrations of 0.5 to 1.0 per cent were thus injected into the specimen. It was hoped

this method might affect the growing point of the stem without checking root growth.

Lanolin Paste:—Where lanolin pastes were employed the colchicine used was 1.0 per cent. The paste was applied by spreading it on the growing points of plants, preferably on buds before they opened.

Single Drop:—In this method a single drop of colchicine solution was applied to the growing tip of a plant. Several repetitions were made during one or more days as the drops dried. A modification was to use a small piece of cotton kept wet with the solution.

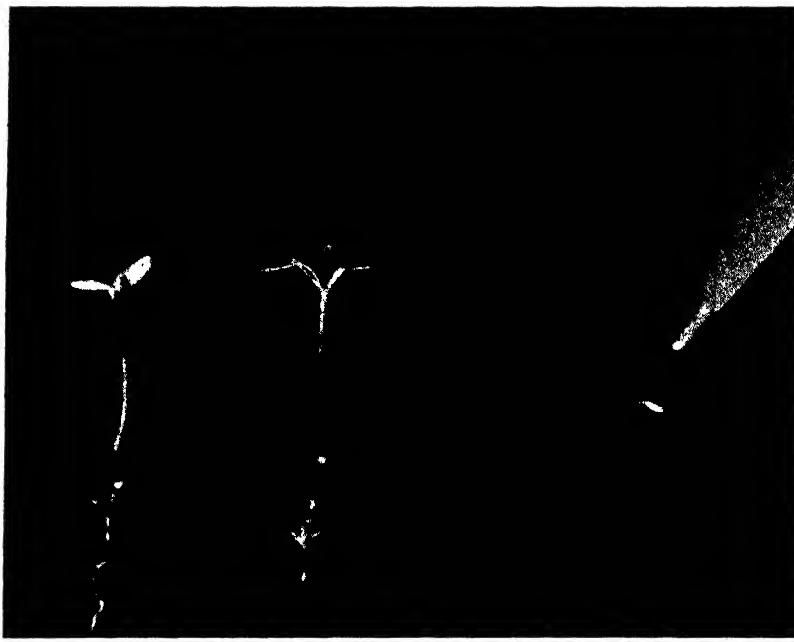

FIG. 1. Petunia seedling from treated seed (right) and untreated seed (left). Despite such an extreme early effect no tetraploids resulted in this plant.

SEED TREATMENT

In seed treatment the seeds were soaked in a solution of colchicine for varying lengths of time. The larger seeds were treated in small vials with just enough solution to cover them. Small seeds were treated by placing them on filter paper in Petri dishes kept moist by the solution. Concentrations of 0.5 to 1.0 per cent were used, and the length of time of treatment was varied from 8 hours to 4 days.

PRESENTATION OF DATA

Plant treatments with lanolin were negative in every case, the same was true with agar solutions. Single drops were found so difficult to apply that few were used. Results were again negative. Solution soaked cotton was easier to use and we believe might be practical, especially for treating axillary buds.

The injection method was used on calla lily *(Zantedeschia aethiopica)* and egyptian onion *(Allium Cepa)*, with 105 bulbs treated. Two of the onions were greatly distorted and carried guard cells of large size throughout the year but onions produced from the top sets were again normal. Since this method did not seriously affect root growth it might be useful in such plants as onions or on other material when large buds are present.

Because of its simplicity the immersion of the growing points in a water solution was most used. Some plants were found to be very easily injured or distorted by this process. Plants belonging to this class with numbers treated are as follows: Begonia *(Begonia sp.)* 10, blue hydrangea *(Hydrangea arborescens)* 2, Carnation *(Dianthus caryophyllus)* 5, lily *(Lilium longiflorum)* 2, manettia vine *(Manettia bicolor)* 10, oleander *(Nerium oleander)* 3, tomato *(Lycopersicum esculentum* and *L. peruvianum x L. esculentum)* 275. In all, 305 were treated with times varying from 15 minutes to 6 hours. Of these only 2 tomatoes became polyploid as indicated by stomatal measurements. These two when grown to maturity were found to have normal pollen and when seed was saved and planted it produced only diploid plants; hence, they were presumably periclinal chimaeras. It is, of course, recognized that plants not carrying large guard cells may have been affected internally and were unrecognized. Manettia vine was most easily injured of all tested. A 15-minute soaking produced serious injury. A little more killed the vine a foot back of the point of immersion.

Plants showing slight distortion or injury from 4 to 60 hours immersion include 386 plants as follows: Bougainvillea *(Bougainvillea glabra)* 3, bryophyllum *(Bryophyllum sp.)* 6, coleus *(Coleus sp.)* 8, gardenia *(Gardenia fortunei)* 4, gladiolus *(Gladiolus sp.)* 102, heliotrope *(Heliotropium corymbosum)* 3, highbush blueberry *(Vaccinium corymbosum)* 105, lantana *(Lantana camara)* 3, lilac *(Syringa vulgaris)* 90, mesenbryanthemum *(Mesembryanthemum crystallinum)* 4, panicum *(Panicum barbinode)* 2, pelargonium *(Pelargonium sp.)* 15, shrimp plant *(Beleprone guttata)* 15, squash *(Cucurbita maxima x C. pepo)* 15, sultana *(Impatiens sultani)* 3, tradescantia *(Tradescantia sp.)* 6. None became polyploids. Generally speaking, the treatment of plants was comparatively difficult and disappointing.

Seed Treatments

Where seeds were soaked 8 hours to 3 days the effect on the seedlings of the following plants was marked. Note that the numbers recorded are seeds that germinated, not the number treated, which was much greater. Begonia *(Begonia sp.)* 300, gourd *(Cucurbita ovifera)* 30, lilac *(Syringa vulgaris)* 850, lowbush blueberry *(Vaccinium pennsylvanicum)* 425, pepper *(Capsicum frutescens)* 80, petunia *(Petunia hybrida)* 400, squash *(Cucurbita maxima x C. pepo)* 100, watermelon *(Citrullus vulgaris)* 73. Of this number, 24 lilac seedlings, 4 lowbush blueberry, 3 peppers, 2 squash, and 1 watermelon did not become normal but were rough and had enlarged guard cells. The pepper, squash, and watermelon were matured and produced abnormal

pollen confirming the earlier diagnosis that these were polyploids. Attention is called to the 24 lilac seedling polyploids from 850 seedlings compared to none from 90 treated growing plants.

The following seeds were apparently affected little by treatments up to 5 days and none proved to be polyploid. Browallia *(Browallia speciosa var. major)* 150, columbine *(Aquilegia canadensis x A. caerulea)* 80, iris *(Iris sp.)* 350, mulberry *(Morus alba x Morus rubra)* 10, stock *(Matthiola incana)* 75.

Including all seedlings treated, the polyploids constitute 1.167 per cent. This corresponds in a general way with the results of others. Considering the comparative ease of its use we believe that where possible seed treatments are the more practical means of inducing polyploidy.

Because of the short hypocotyls from treated seed; germinating the seed in a germinator was found desirable with a transfer immediately to a special seedling-flat where extra care could be given until normal growth was resumed. Washing of the seed as suggested by Derman (1) might overcome the difficulty but was not used in our material.

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Methods and Problems in Raspberry Breeding[1]

By George L. Slate, *N. Y. State Agricultural Experiment Station, Geneva, N. Y.*

This is a brief summary of the methods, problems and objectives of the raspberry breeding project at Geneva.

Crosses are made in the field, the flowers being emasculated by cutting around the base of the bud with a small scalpel. Close observation is necessary to make certain that no anthers are overlooked or that none have started to shed pollen at the time of emasculation. Open flowers and buds too small to work are removed. The emasculated clusters are protected from insect visitation with white paper sacks secured with a wooden tree label on which is recorded the date of emasculation. The emasculated flowers are allowed to develop for 3 days before they are pollinated.

Pollen is secured by bagging several laterals before the buds have opened. The flowers which open in the bags are picked off and brushed over the emasculated flowers. This method ensures an abundance of fresh pollen. On the label at time of pollination is recorded the date and number of pollinated flowers. A few days later the paper sacks are torn open to let in more light and provide room for growth. Before the fruit ripens the paper sacks are replaced with gauze bags which protect the fruit from the birds and collect the berries as they ripen and drop. Usually about five bags totaling around 100 flowers are pollinated for each cross. It is well to pollinate more flowers than needed as some bags are always lost accidentally.

The seeds are not cleaned, but the ripe berries are mashed up with sand, the mixture dried for a few days and then sown in flats of the standard greenhouse soil mixture. Sterilized soil is preferable as it eliminates weeding. Damping off has not been a problem whether the soil is sterilized or not. The seed flats remain in the cold frames until early March when they are brought into a cool house and then into a warm house. It is not advisable to bring the seedlings along too fast as they grow very rapidly and will become too large for safe moving to the field before the frost free date, which in 1944 was May 22.

Seedlings are transplanted from the seed flats to other flats or to 3-inch pots. The pots are much superior to the flats as the intermingling roots in the flats result in much injury to the young plants if removal to the nursery row is delayed. Thus far the seedling plants have been put in the nursery the first summer and then moved to the field in the fall. It is believed now that with potted plants and a good piece of ground the seedlings could be planted directly from the pot to the field without the intervening period in the nursery. A year would be saved, but the labor cost the first summer would be greater.

In the fruiting planting a spacing of 7 x 7 feet has proved satisfactory. The plants grow 2 years and selections are made the third season. Usually about six plants of each selection are taken for a second test,

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but with very promising seedlings all plants obtainable are used. If enough plants are available, the selection is also sent to the mosaic test plant in the Hudson Valley. Selections are made on the basis of merit, characteristics to be used in breeding and the need for material for another generation.

Seedlings are sometimes described briefly, but this method requires so much labor that it has been abandoned. At present a dozen berries of each seedling in a population are collected and brought together on a large table. The seedlings are then classified as large, medium, and small, and counts of each class are recorded. The same procedure is used for other characteristics. By this method the same person passes on every seedling and the varying judgment of different workers is eliminated.

The number of seedlings needed to realize the potentialities of a cross, or to indicate its merits, has not been determined. In certain populations the level of merit is high and these combinations should be repeated, especially if the population is not large. In other populations the level of merit is low, and it is doubtful whether additional large populations from these combinations would produce seedlings substantially superior to those already raised. Seedlings of outstanding merit are usually found only in populations containing a high proportion of meritorious individuals. Populations of 50 to 100 seedlings are probably sufficient to indicate the possibilities of a combination. Populations of 500 to 1000 will usually realize the profitable potentialities of a combination.

The principal method of breeding employed thus far has been the crossing of varieties and selections possessing the desired characteristics. With the red and black raspberries this has been a satisfactory method thus far and satisfactory progress has resulted. It has been the practice to make a number of different crosses with the same object in mind. Experience indicates that it is not possible to predict in advance which of several combinations will produce seedlings possessing the desired characteristics. One may be certain that many of the combinations tried will be unsatisfactory. By growing a number of crosses in one year an opportunity is afforded to compare the different combinations and obtain an estimate of the value of certain varieties as parents.

In the breeding of autumn-fruiting raspberries, using chiefly derivatives of Lloyd George, F_2's have been produced from sib crosses, back crosses and selfs. In all of these types of matings there has been a marked reduction in the vigor of the resulting seedlings and mortality has been heavy. It is possible that very large populations with rigid culling of weaklings in the seed flat and nursery might produce individuals with the desired characteristics in the F_2. However at the present time it would appear to be more profitable to develop a line of breeding in which full advantage is taken of the phenomenon of hybrid vigor. This involves the mating of types not closely related. In the case of the autumn-fruiting raspberries it is now proposed to produce a series of seedlings by combining autumn-fruiting selections of *Rubus strigosus* with various American varieties such as New-

burgh and Latham. These will be combined with Lloyd George derivatives, which will contribute large size, mosaic klendusity and the autumn-fruiting habit. The crossing of these two unrelated groups should result in much more vigorous progenies than can be obtained by intercrossing the large-fruited descendants of Lloyd George that are now so popular with raspberry breeders.

Some red raspberry crosses that have produced populations outstanding in vigor at Geneva are Lloyd George x Newman, Lloyd George x Newburgh, Lloyd George x Herbert, Lloyd George x Viking and Lloyd George x N. Y. 1950. Reciprocals of the above have been equally vigorous. Taylor x Cuthbert produced some unusually vigorous seedlings. All of these combinations have been between unrelated varieties.

With black raspberries there is little if any loss of vigor from inbreeding and on the basis of present evidence there seems to be no reason why the mating of closely related varieties should be avoided.

The purple raspberry is produced by crossing the black raspberry with the red raspberry and the hybrid vigor to be expected from this species cross is evident in most of the populations raised at Geneva. Several progenies from crosses between F_1 purple selections have been raised as well as populations from the selfing of purple seedlings. The seedlings resulting from both lines of breeding are a miscellaneous lot, varying considerably in vigor and usually much less vigorous than their parents. Much sterility is evident and the fruits are usually small and generally inferior. The F_2 segregants did not include any typical red or black raspberries.

Improvement in the purple raspberry will evidently have to be brought about by direct crosses between black and red raspberries. Lloyd George which has been an excellent parent in red raspberry breeding has given poor results in breeding purple raspberries. Crosses between the Dundee black raspberry and Newburgh red raspberry, and Bristol black with a sib of Newburgh have produced the best seedlings so far. Crosses between Bristol and Taylor, Marcy, Milton and N. Y. 14477 have produced fair, but not outstanding progeny that will have to show considerable resistance to mosaic if they are to be of much value.

Mosaic is by far the most important disease of raspberries in New York State. In the central and western parts of the state its control by rogueing is feasible but in the Hudson Valley it is very difficult to maintain a planting of a susceptible variety free from mosaic, or even to keep it in profitable production unless it is tolerant of the virus.

The control of mosaic by breeding may be achieved by two methods. Varieties tolerant of the virus may be developed which may be grown satisfactorily even though infected. Varieties of this type may be all right in themselves, but are a menace to susceptible varieties growing nearby. The method we are following in the red raspberry breeding at Geneva is the production of varieties that are klendusic. A klendusic variety is one that does not become infected with the virus, pre-

sumably because of some relation between the plant and the vector which makes infection difficult or impossible.

The first attempt at the Geneva Station to produce a variety klendusic to mosaic was made in 1921 by Wellington who crossed the Herbert and Newman varieties. Wellington had observed for several years that Herbert remained free from "yellows" as it was then called. The klendusity of the Newburgh variety, a product of this cross, did not become evident for several years. Eventually it became evident that Newburgh rarely became infected with mosaic in central and western New York, but in the Hudson Valley it became infected rather rapidly.

In 1925, Lloyd George was first used in breeding at Geneva because of the large size of the berries. In 1934, nine varieties and 35 selections, many of which were derived from Lloyd George, were planted in a test plat in the Hudson Valley beside a block of Latham, Chief and Newburgh that was completely infected with mosaic. By the end of the third growing season 23 of the 35 selections were still free from mosaic while nearly all plants of the varieties and other selections were infected. The virus-free selections were all seedlings of Lloyd George. Additional seedlings have been tested in the valley from time to time and similar results have been obtained. Usually at the end of the second growing season all plants of non-klendusic selections are infected and all plants of the klendusic selections are virus-free and remain that way indefinitely. The rapid spread of mosaic in the Hudson Valley thus provides us with an excellent opportunity to test the klendusity of our selections to mosaic under natural conditions of spread. All of our selections are being so tested.

With black raspberries, we have not been so fortunate and we have not yet discovered mosaic klendusic clones. There are virus-free black raspberries growing wild near cultivated red raspberries and these will be tested on a larger scale. Plans are under way to grow populations of black raspberry seedlings under conditions favoring the rapid spread of mosaic. A clone as klendusic to mosaic as Milton and Indian Summer red raspberries would be of inestimable value to the breeder.

Strawberry Breeding Problems

By JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

THE STRAWBERRY is the most important small fruit grown in North America. Its popularity can be attributed largely to two important facts: First, its adaptability — it can be grown on most soil types from the tropical areas of the South to as far north as central Alaska; Second, its dessert and aromatic quality.

Although the strawberry can be grown over a wide range of territory and on many soil types the fact remains that most of the commercial varieties are very limited in their areas of adaptability. It is therefore the job of the plant breeder in each major area to breed the very best variety to meet the needs of the growers and the commercial requirements. Some of the major strawberry breeding problems now being considered by the plant breeders in the United States are as follows:

PLANT CHARACTERS

Vigor and plant adaptability. Vigor of the plant should be the first major factor to be considered for unless satisfactory crops can be produced it will not be profitable to the grower. The South must have a short day plant, that is, one that will begin growth early in the season. The northern varieties when grown in the South make very little growth until the day length increases late in the season at which time a satisfactory crop can not be produced. In the northern areas a plant is needed that will produce a satisfactory foliage which is not overly vegetative as many of the short day plants have a tendency to make when grown in the North. In areas of high humidity in fruiting periods it would be best for the plant to have an upright foliage, however, there should be enough foliage to partially shade the fruit from the sun. In regions where frost damage is severe it is best to have a short, compact plant which will protect the early blossoms. The best type of fruiting branch will vary in different sections of the country. For example, in the South upright branches which produce one or two flowers per day over a long period of time (50 to 60 days) are desired, while in certain areas of the East or North where the production season is short, one would want a compound or flush type of fruiting branch. In the South it is highly desirable to have varieties which are resistant to summer heat as well as resistant to cold damage to the buds in the crown. In the far North and central states considerable attention is given to breeding varieties showing extreme cold resistance. Throughout the country, varieties suitable for different soil types and altitudes are essential.

PLANT PRODUCTIVITY

In the strawberry producing areas of Texas, Louisiana, parts of Alabama, and Florida where the crop is grown as an annual there must be varieties which will produce a large number of plants. From

one mother plant as many as 20 desirable plants should be produced in order for it to be considered worthwhile saving as a variety for this area. A more desirable seedling should produce as many as 50 to 75 No. 1 plants. In areas further north and west where the crop is grown on the matted row system a variety which does not produce an excessive number of plants is desired. It has been found that good plant producing seedlings can be obtained by crossing cultivated varieties with wild species. Where many of the northern varieties are not suited to southern conditions the desirable type of plant producers can often be obtained from them by selfing or crossing.

Disease Resistance

This has been given a great deal of attention in the strawberry breeding program. Throughout the humid areas of the South leaf spot and scorch are the two major diseases and before giving a seedling a field trial it is tested for resistance to these diseases. In the eastern areas red stele and black root are the two major diseases. At the present time resistant varieties, particularly to red stele are now being released by a number of stations, particularly the U. S. Department of Agriculture, Beltsville, Maryland, and the New Jersey Agricultural Experiment Station. Of the virus diseases yellows seems to be the worst. This can largely be eliminated by using varieties which do not carry the factor for this disease. There are probably other virus diseases which as yet have not been identified.

Insect Resistance

While very little breeding work has been done toward insect resistance the writer feels that more emphasis should be given to this phase, particularly breeding varieties resistant to red spider and crown and root nematode. Indications in Louisiana are that it is possible to breed varieties showing at least some degree of resistance to red spider. Seedlings having leaves growing more upright show greater resistance than those which are prostrate, probably due to the fact that the more upright leaves are more exposed to sun and rain and give less protection to the insect.

Fruit Productivity

For best results the plant must have vigor, resistance to insects and diseases and show general adaptability to a given area. However, unless a given variety shows a profitable yield of desirable fruit it will not be worthy of further consideration. In the lower South or Pacific Coast areas the plants should fruit over a long period of time producing one or two ripe berries per plant each day for a period of 50 to 60 days or longer. This should make a total yield of one to two pints of berries per plant. In the North and Northwest where the fruiting period is short (from 2 to 3 weeks) the yields should be as high or higher per plant. Practically all the major producing areas should have early, medium, and late varieties. This makes for uni-

formity in handling and marketing over a longer period of time for fresh market as well as for processing. This will help distribute hazards such as frost which might seriously damage the crop where just one variety is being used. In each area, however, the varieties should be similar so as to meet the market demands.

In certain areas of the North and East, everbearing varieties are in demand particularly with home gardeners. Additional work is needed to improve the present varieties.

Fruit Characters

The varieties selected should produce uniform berries throughout the season. For shipping the color of the fruit should be a bright red which will not turn dark on display. Shipping and handling qualities should be combined with good edible qualities. Quality of the fruit is largely determined by the sugar-acid ratio plus aroma. For dessert quality, most people prefer the sweet flavor to predominate over the acid flavor, however, the acid taste is necessary in order to accentuate the strawberry flavor. A seedling, to be classed as having an excellent dessert quality should have a refractometer reading of 8.5 to 10 per cent soluble solids, to be classed as good should vary from 7.5 to 8.4 per cent, and poor — from 6.5 to 7.4 per cent. The breeder should keep in mind total food composition. This means high total solids and high soluble solids which is largely reflected as sugar. At the same time the vitamin content, both A and C, should be kept in mind and if possible determinations made on a seedling before it is released. Many of the breeders are now determining the vitamin C or ascorbic acid before releasing a seedling. The Louisiana Station uses the Fairmore variety as a standard. Its average of five determinations from early to late in the season is 80 milligrams of ascorbic acid per 100-gram sample and would be classed as excellent in this respect. Seedlings classed as good should contain 70 milligrams, fair — 60 milligrams, and poor — 50 milligrams per 100-gram sample. Many of the selected seedlings are now running 70 or better. In order to obtain an average of the ascorbic acid content in the strawberry under various seasonal conditions it should be analyzed from four to five times during the season and over a period of several years.

As mentioned previously, aroma is one of the factors which go to make up flavor of the fruit and should not be overlooked in the breeding program. This character is generally dominant in the wild species and the Louisiana Station is using the *Fragaria grayana* in its breeding program to breed seedlings for higher aroma.

Type of Calyx

A shipping berry should have a calyx resistant to leaf spot and one which will stay green throughout the period of shipping and handling. Where a variety is bred entirely for quick freezing or canning, the calyx should be easy to remove or remain attached to the plant at time of picking.

Processing Berry

A berry for the quick freezing trade should be a very high yielder, medium to firm, should have an excellent mild to subacid flavor, strong aroma, and a dark to very dark red color. For canning and preserving where whole berries are to be packed they should be uniform, dark red in color, firm, somewhat acid, highly flavored, and have a strong aroma.

While the above has been an attempt to summarize some few of the major problems involved in the strawberry breeding program in the United States it is by no means all. As in any breeding program three or more major factors are sought for but in reality hundreds or even thousands of characters must be considered. It will be practically impossible to obtain a variety which possesses all of the desired qualities. If, however, the plant breeder will take advantage of important characters obtained by fellow workers and use the new introductions in the breeding program, a gradual combination of desirable characters can be bred into superior seedlings. Of all of the characters sought for, it is the opinion of the writer that major emphasis should be placed on the dessert quality of the berry.

The Place of the Lupton Variety in the New Jersey Strawberry Breeding Program[1]

By J. HAROLD CLARK, *N. J. Agricultural Experiment Station, New Brunswick, N. J.*

THE STRAWBERRY breeding project at the New Jersey Experiment Station was started in 1928 and crosses have been made every year since that time. The principal objective has been the production of better commercial varieties, especially those which ripen very late. Five selections have already been named.

It is rather difficult to summarize the results of 16 years of breeding work with the strawberry, involving over 40,000 seedlings, in such a way that the information will be of value to other breeders. This has not been a genetic study and as reported by Darrow (1) there are very few contrasting characters in the strawberry which lend themselves to genetic analysis. If we assume that the basic haploid chromosome number of the strawberry is seven (as in *Fragaria vesca*), then the cultivated varieties, having 28 pairs of chromosomes, are octoploids, hence not well adapted to the working out of genetic ratios. The results of an experiment such as this must, therefore, be measured primarily in terms of varieties and selections that possess characters superior to those found in other available varieties. Although many characters are noted by the strawberry breeder, probably the most important are productiveness, edible quality, color and appearance, shipping quality which would include flesh firmness and skin toughness, and resistance to pests and unfavorable conditions. Some of these characteristics, particularly productiveness, could be evaluated quantitatively but such studies require considerable time and effort which might possibly be expended more profitably in raising another generation of seedlings.

The making of a complete report at any specific time is further complicated by the fact that the breeding work has been a continuous process with additional crosses each year, new selections made, and old ones discarded. Certain progenies under observation any one year may be from comparatively recent crosses and contain a relatively large number of selections whereas other progenies are the result of earlier crosses and have been more severely culled down. The percentage of seedlings of each cross which is retained for a second test gives some measure of the value of that cross. However, a simple tabulation of the percentage saved does not give information as to whether they were saved because of immediate value or simply because they might be useful for further breeding.

The improvement of the strawberry is a slow process involving careful selection of parents which will transmit desirable characters, the raising of many seedlings, and the efficient selection of seedlings for further test and propagation. It should be of some value to other breeders if the breeding behavior and influence of individual varieties

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could be traced through several generations. This paper is an attempt to do that briefly for one variety.

The following varieties were used in various combinations in 1928, the year the project was started:—Aberdeen, Gandy, Howard 17, Lupton, Wyona, Pearl and Mastodon. Additional parents used in 1929 were Beacon, Bouquet, Chesapeake, U. S. D. A. 875 and one unnamed selection. In 1930, additional varieties used were Redheart, Parcell, Teddy Roosevelt, U. S. D. A. 652, U. S. D. A. 682 and another unnamed selection. Beginning in 1931 and each year since that time most of the crosses were between various New Jersey selections. In 1931, however, several crosses were made with Fairfax as one parent; U. S. D. A. 854 and two selections of *Fragaria chiloensis* from the Pacific Coast were also used. In later years Dorsett, Culver, and Catskill have been used to a limited extent as well as certain everbearing varieties, in addition to Mastodon.

Practically all of the varieties listed above are represented in greater or less degree in the ancestry of some of the various selections now under test. Space does not permit a detailed report at this time on all the varieties used as parents; therefore attention is limited primarily to the Lupton variety. At the time the breeding work was started, Lupton was by far the leading variety in New Jersey so far as acreage is concerned, especially in the important commercial areas in the southern part of the state. In order to produce better commercial varieties for New Jersey, it was obviously necessary to develop one or more that would be more profitable to grow than Lupton.

The Lupton variety originated in 1905 as a cross between Joe and Gandy by Mr. M. D. Lupton, Newport, N. J. Quoting Hedrick (2) "It is about the handsomest of commercial strawberries but one of the poorest in quality, the Ben Davis in the strawberry family." This statement describes the variety very aptly and explains why it should be replaced. Lupton ripens rather late, has a bright, light red color which holds well during shipment, is large and very attractive but extremely dry. This dryness makes it a very fine shipping variety but a very poor berry to eat. Most of the berries in southern New Jersey are purchased by truckers who are interested in the appearance of the fruit on arrival in the wholesale market rather than in its edible quality and who have been willing therefore to pay high prices for Lupton. A variety to replace Lupton, which would appeal to the buyers, must have very fine appearance and shipping quality, plus edible quality and other good characters.

In 1928, Lupton was crossed with Aberdeen, Howard 17, and Pearl and in 1929 with Howard 17, Chesapeake, Pearl, Wyona, and an unnamed seedling. The offspring of all these crosses were rather uniformly vigorous, moderately productive with fruit that was very large and attractive but soft, very dry, and very poor in edible quality. As will be noted in Table I, a smaller percentage of Lupton seedlings was saved during these 2 years than of seedlings not having Lupton as a parent. All of the 26 selections saved from the first 2 years' crosses were discarded after the second test except one, N. J. 72, Lupton x Aberdeen. The selections, because of very poor quality, were not

at all promising and it appeared doubtful whether this line of breeding should be continued. It seemed important, however, to make use of Lupton's good qualities, which were not available to a similar degree in any other variety. The obvious need was for a very firm and high quality variety to combine with it. In 1933, therefore, N. J. 72 was crossed with N. J. 211 which was a seedling of Redheart x Aberdeen. The offspring were somewhat more promising than the original seedlings of Lupton but the Lupton dryness and poor quality were still present. In 1934, N. J. 72 was crossed with Fairfax, known at the time as U. S. D. A. 613. Fairfax with its firmness and high quality seemed to be just what was needed to supplement the good qualities of the Lupton seedling and the result was that 15 out of 168 seedlings were saved for second test, an extremely high percentage. The offspring were relatively uniform, vigorous, productive, large, almost all brightly colored, firm, smooth and with large green calyces. The edible quality varied from that of N. J. 72, which is poor, almost to that of Fairfax which is very good. This cross was noted at the time as being probably the most promising of all that had been observed up to that date.

TABLE I—Comparison of Progenies Descended from Lupton With Those from Other Crosses

Year Crosses Were Made	One Parent Lupton or a Descendant of Lupton				Parents Other Than Lupton or Its Descendants
	No. of Crosses	No. Seedlings	No. Saved for Second Test	Per Cent Saved	Per Cent Saved
1928	4*	458	21	4.6	5.7
1929	5*	138	5	3.6	4.5
1933	1	139	3	2.2	3.4
1934	3	283	16	5.7	2.1
1937	5	465	12	2.6	2.3
1938	7	504	23	4.6	3.1
1940	2	125	2	1.6	2.4
1941	15	882	16	1.8	1.6
1942	26	1,686	40	2.4	1.5
——	–	4,680	138	2.9	2.9

*Lupton itself used as one parent.

Again in 1937, N. J. 72 was crossed with Fairfax and some of the seedlings of N. J. 72 x Fairfax were crossed with other selections, giving seedlings which might be called ¼ Lupton. In 1938, and again in 1940, ¼ Lupton selections were used in several crosses to provide seedlings ⅛ Lupton. In 1942, both ¼ and ⅛ Lupton selections were used to give a rather large number of seedlings that were $^{1}/_{16}$ Lupton. It is interesting to note that these seedlings, although having Lupton as only one great, great grandparent, tend to be large in size with bright color, attractive green caps, and other characters traceable to Lupton, but with much better quality than the seedlings of earlier crosses. They are not so dry as Lupton and so may not ship quite so well but they are reasonably dry and quite firm and are considered to have good shipping quality.

After the 1944 fruiting season all the selections from the breeding

up to this point which have been through second tests and which are to be retained for further tests were grouped into three classes:

Class 1, those which are to be propagated rapidly and probably named unless some fault develops.

Class 2, those which are promising but not quite good enough to name unless they show up better in future years.

Class 3, those which are not quite so good as Class 2 but have characters which may make them of value for some special purpose.

The ancestry of the selections in each of these classes was examined to determine how many of them are descendants of Lupton. In Class 1, which contained a total of ten, one selection is ¼ Lupton and one is ⅛ Lupton. In Class 2, there are 41 selections of which two are ¼ Lupton and six are ⅛ Lupton. In Class 3, with a total of 55 selections, eleven are ⅛ Lupton. Considering the three classes together we find that of all the seedlings fruiting before 1944 and which had Lupton, or a descendant of Lupton, as one parent 0.70 per cent are still retained as being worthy of further testing. Of all other seedlings fruiting during the same period only 0.25 per cent are still retained. Apparently the Lupton has proved itself a good ancestor for strawberry varieties to be grown under New Jersey conditions.

Conclusions

The data indicate that Lupton has a strong tendency to transmit its characters, both desirable and undesirable, to its offspring and to succeeding generations. By continued crossing with other varieties, and especially with Fairfax or its seedlings, good edible quality was obtained and the good qualities of Lupton were retained. The Lupton has characters which made it a very good parent but it took at least two to three generations to eliminate the undesirable characters.

Literature Cited

1. Darrow, Geo. M. Strawberry improvement. *U. S. D. A. Yearbook of Agriculture*. 1937.
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Pollination of the Rabbiteye Blueberry and Related Species

By E. M. MEADER and GEORGE M. DARROW, *U. S. Department of Agriculture, Beltsville, Md.*

IN VIEW of a probable increase in the planting of the rabbiteye blueberry, *Vaccinium ashei* Reade, in the South, it has become desirable to determine whether varieties of this species require cross-pollination. Heretofore pollination studies of the blueberry (Coville (3), Beckwith (2), Merrill (5), Bailey (1), Merrill and Johnston (6), White and Clark (8), and Morrow (7)) have been confined to cultivated varieties of the northern highbush blueberry, *V. australe* Small. Except for Merrill and Johnston (5, 6), the earlier workers found cross-pollination necessary or more favorable in the case of the highbush blueberry varieties. Recently, Morrow (7) under greenhouse conditions has shown that a greater set of fruit, earlier maturity, and much larger berries with a higher proportion of fully developed seeds per berry resulted from cross-pollination than from self-pollination in the varieties Weymouth, Scammell, and Dixi. Correlation between size of berry and number of large or plump seeds for varieties of the northern highbush has been shown by White and Clark (8) and Darrow (4).

Recent investigations (unpublished) indicate that the rabbiteye blueberry has been derived from several Vaccinium species indigenous to the South. Some of these species possess desirable horticultural qualities that may be particularly useful in a breeding program. The need for information on their pollination requirements suggested their inclusion in the pollination studies.

METHODS

Potted plants of varieties of the rabbiteye blueberry, together with avaliable plants of several other species and of hybrids, were moved into a warm greenhouse to flower. For the most part, plants were brought in on January 21, 1943. Those rabbiteye varieties and other species that were known to flower sooner than plants with which crosses were desired were moved into the warm greenhouse later.

Morrow's (7) techniques of pairing shoots on individual plants and of extracting seeds with a Waring blender were used, with modifications as noted hereafter. Pollination of the Myers variety was started on February 15. Other varieties and species were pollinated in succession as they came into flower. With the rabbiteye varieties, individual racemes were paired, but with some of the other plants shoots were paired. Flowers to be crossed were emasculated. No flowers were removed except those broken accidentally and a few used as a source of pollen. On each of the racemes and shoots that were paired equal numbers of flowers were self- and cross-pollinated at one time. On later dates, the remaining flowers on the shoots or in the racemes were pollinated after they had opened. The last pollinations were completed about March 15. The plants were left in the greenhouse until all berries had ripened. Fully ripe fruits were gathered every

other day. A berry was considered ripe on the day when it had lost all red color and had become either blue or black, the characteristic color for the variety or species.

Results with Rabbiteye Varieties

Fruit Set: The 10 varieties of rabbiteye blueberry are listed in Table I in ascending order of the percentage of flowers setting fruit when self-pollinated. They fall into three groups: (a) Nell, Black

TABLE I—The Effect of Self- Versus Cross-pollination on Set of Fruit, Time of Ripening, Berry Weight, and Seed Content of Rabbiteye Blueberry Varieties

Pollen Used	Number of Flowers	Fruit Set (Per Cent)	Average Days to Maturity*	Number of Berries Weighed	Average Weight: Berries (Mg)	Average Weight: Seed Per Berry (Mg)	Increase in Weight for Cross-pollinated Berries (Per Cent)
			Nell				
Nell	84	0	—	—	—	—	—
Ruby	104	26.0	84.1	0	—	—	—
			*Black Giant***				
Black Giant	138	0	—	—	—	—	—
Clara	138	64.5	—	—	—	—	—
			Clara				
Clara	174	2.3	98.5	4	671	8.4	—
Myers	160	61.8	89.5	99	857	9.5	28
			Hagood				
Hagood	245	3.3	101.1	8	655	10.3	—
Black Giant	191	54.4	97.6	103	892	20.2	33
Myers	177	60.0	96.6	106	866	20.0	32
			Myers				
Myers	671	9.2	122.8	40	326	5.8	—
Owens	231	87.9	98.6	180	906	29.5	178
			Pecan				
Pecan	117	9.4	112.6	11	446	4.2	—
Blueboy	110	67.6	111.1	74	761	10.8	71
			Anne				
Anne	147	11.6	122.9	20	475	12.2	—
Owens	44	63.6	128.0	28	724	34.0	52
Myers	80	78.8	133.0	59	665	21.4	40
Black Giant	46	84.8	120.3	40	757	27.4	59
			Suwanee				
Suwanee	180	27.8	115.5	50	503	5.0	—
Hagood	118	79.7	116.1	107	646	20.9	28
Myers	208	80.8	112.6	148	646	18.4	28
			Scott				
Scott	161	32.9	113.3	0	—	—	—
Myers	122	67.2	116.1	0	—	—	—
			Blueboy				
Blueboy	54	72.2†	122.4	19	387	14.9	—
Myers	42	73.8	116.0	29	458	21.9	18
Owens	16	87.5	114.1	14	653	25.1	69

*Difference between weighted-mean pollination date and weighted-mean ripening date.
**From 1944 data taken 4 weeks after pollination.
†P value in chi-square test indicates no significant difference at 5 per cent level between the set from self- and cross-pollination for this variety; all other varieties have differences significant at the 5 per cent or 1 per cent level.

Giant, Clara, Hagood, Myers, Pecan, and Anne, which are relatively self-sterile; (b) Suwanee and Scott, which set fruit on nearly a third of their flowers when self-pollinated as compared with over two-thirds when cross-pollinated; and (c) the Blueboy, whose flowers set fruit equally well when selfed or when crossed. Where pollens of two or more varieties of rabbiteye were used for cross-pollination, there was no statistically significant difference between varieties as sources of pollen.

When Myers (6x) was pollinated by other species (Table II), *Vaccinium virgatum* Ait., the tetraploid of the polyploidal series to which the rabbiteye belongs, (Darrow *et al.* to be published) produced as high a fruit set as was obtained when another rabbiteye variety (Owens) was used. The set of fruit with the pollen of two selections of another hexaploid species (*V. constablaei* Gray) which is found in the high mountains of western North Carolina, as well as that with the pollen of the tetraploid northern highbush (Atlantic, Pemberton, and No. 17–19) was greater than with self-pollination.

Days to Maturity:—The number of days to maturity for crossed berries of the rabbiteye varieties when other rabbiteye varieties or related species were the pollen source tended to be less than for the selfed berries. Myers, an important variety and one for which data seem adequate, matured its crossed berries 24 days earlier on the average than it did berries set by self-pollination. The number of days to maturity for selfed berries of most of the rabbiteye varieties is only suggestive since so few selfed flowers set fruit that a fair weighted-average ripening date for the selfed berries could not be obtained. The time that elapsed between harvesting a number of ripe crossed berries before a single selfed berry of the variety was ripe is as follows: Clara, 21 days; Suwanee, 8; Myers, 22; Hagood, 10; Blueboy, 4; Pecan, 6; Anne, 10; and Scott, 20 days.

Fruits of Myers (6x) set by pollen of Atlantic (4x) however ripened along with selfed berries of Myers (Table II), while fruits set by pollen of Pemberton (4x) ripened an average of 10 days later than did the self-pollinated berries.

Size of Berries:—Without exception, crossed berries of the rabbiteye varieties studied averaged larger than the selfed berries. The percentage increase in berry weight due to cross-pollination within the species was from 18 to 178 per cent. Berries resulting from the use of pollen of other species averaged larger in all cases than the selfed berries and the percentage increase was from 18 to 137 per cent. However, the largest berries occurred when the cross-pollination was within the species.

Seed Content:—The average total weight of all the seeds per berry of the rabbiteye varieties (Table I) was greater for the crossed than for the selfed berries in all cases. The greater seed content with cross-pollination was noteworthy for the relatively self-sterile variety Myers, crossed berries (Owens for pollen parent) having 29.5 mg. and selfed berries 5.8 mg. of seed per berry. Two varieties, Clara and Suwanee (Table II), which were studied in detail had far more plump seeds in the crossed berries than in the selfed berries.

TABLE II—THE EFFECT OF SELF- VERSUS CROSS-POLLINATION FOR HEXAPLOID, PENTAPLOID, TETRAPLOID, AND DIPLOID BLUEBERRIES

Pollen Used‡	Number of Flowers	Fruit Set (Per Cent)	Average Days to Maturity†	Number of Berries Weighed	Average Berry Weight (Mg)	Total No. of Seeds Per Berry	Average Weight of Seed Per Berry (Mg)	Fully Developed Seeds Per Berry		Increased Average Berry Weight by Cross-Pollination (Per Cent)
								Number	Weight (Mg)	
					Hexaploid—Clara					
Clara (6 X)‡	174	2.3	98.5	4	671	16	8.4**	4	3.5	—
Myers (6 X)	160	61.8	89.5	99	857	18	9.5*	11	7.9	28
					Hexaploid—Suwanee					
Suwanee (6 X)	180	27.8	115.5	50	503	23	5.0	1 to 2	1.1	—
Hagood (6 X)	118	79.7	116.1	107	646	54	20.9	27	15.0	28
Myers (6 X)	208	80.8	112.6	148	646	53	18.4	18	10.2	28
					Hexaploid—Myers					
Myers (6 X)	671	9.2	122.8	40	326	—	5.8	—	—	—
Owens (6 X)	231	87.9	98.6	180	906	—	29.5*	—	—	178
V. constablaei (Cov.)§ No. 3 (6 X)	218	52.8	105.8	112	625	—	15.7*	—	—	92
V. constablaei (6 X)	109	57.1	86.0	0	—	—	—*	—	—	—
V. virgatum (4 X)	61	86.9	93.8	46	774	—	25.2	—	—	137
Atlantic (4 X)	100	67.0	123.0	54	393	—	8.4*	—	—	21
Pemberton (4 X)	73	20.5	133.3	13	383	—	4.9	—	—	18
No. 17-19 highbush (4 X)	147	14.9	97.7	0	—	—	—	—	—	—
					Hexaploid—V. constablaei (Cov.)§					
Myers (6 X)	50	42.0	49.3	0	—	—	—*	—	—	—
					Pentaploid—M-29 (Katharine X V. ashei)					
M-29 (5 X)	46	0	—	—	—	—	—	—	—	—
No. 2 (Dixi X *V. ashei*) (5 X)	24	12.5	106.3	3	1067	4	0.2	0 to 1	—	—
Myers (6 X)	78	56.4	85.8	45	899	4	1.4*	1 to 2	1.2	—
Stanley (4 X)	118	43.2	103.7	28	763	5	1.7*	1 to 2	1.2	—
					Tetraploid—V. virgatum					
V. virgatum (4 X)	209	0	—	—	—	—	—	—	—	—
DN76—highbush (4 X)	262	1.5	90.8	0	—	—	—*	—	—	—
A91—highbush (4 X)	323	5.9	85.2	0	—	—	—*	—	—	—
V20—highbush (4 X)	28	7.1	93.0	0	—	—	—*	—	—	—
Pemberton (4 X)	247	7.7	90.0	0	—	—	—*	—	—	—
Atlantic (4 X)	284	27.1	89.7	0	—	—	—*	—	—	—
No. 5, Sugar Valley (*V. alto-montanum*) (4 X)	153	1.3	93.0	0	—	—	—*	—	—	—
					Tetraploid—V. myrsinites					
V. myrsinites (4 X)	239	79.1	98.1	186	213	27	7.0	9	4.0	—
DN76—highbush (4 X)	67	58.2	95.9	38	188	—	5.0	—	—	-12
Orvis Williams (4 X)	14	64.3	91.9	10	208	34	7.6	8	3.7	-2
Owens (6 X)	54	77.8	99.6	33	266	37	8.4	9	3.0	25
V. constablaei (Cov.)§ (6 X)	79	19.0	110.4	11	274	25	4.3	4	1.8	30
					Diploid—V. tenellum (Hunt.)§					
V. tenellum (Hunt.)§ (2 X)	130	29.2	96.6	38	157	23	3.2	2	0.8	—
V. tenellum (Ivan.)§ (2 X)	120	82.5	84.5	80	257	64	10.6	17	5.4	64
V. myrtilloides (Me-3305-A)§ (2 X)	19	89.5	93.2	17	318	90	12.6*	31	9.2	103
					Diploid—V. darrowi					
V. darrowi (2 X)	265	15.1	103.7	40	123	—	1.2	—	—	—
V. elliottii (H.C. 1345)§ (2 X)	98	62.2	68.9	40	161	—	2.1	—	—	31
V. pallidum (S.C.)§ (2 X)	186	71.5	74.3	133	251	—	5.3*	—	—	104

*Seeds planted and numerous seedlings growing March 1944; lots without asterisk were not planted.
**One seedling growing March 1944.
†Difference between weighted-mean pollination date and weighted-mean ripening date.
‡Somatic chromosome numbers are indicated.
§Selection name or number of the clone in parenthesis.

Results with Other Species and Hybrids

Fruit Set:—A pentaploid selection (M-29), a hybrid between the northern highbush and rabbiteye, (Table II) set about one-half of its flowers and produced a good crop when pollen of each of the two parental species was used. It failed to set any fruit when selfed with the limited amount of pollen found in its own flowers. When pollen from another pentaploid was used, M-29 set a few berries. Thus the pentaploid M-29 which is self-sterile is remarkably fruitful with cross-pollination both in the greenhouse and under field conditions.

A plant of *Vaccinium virgatum* (4x) (Table II) proved to be self-sterile. No other clone of the same species was available, but crosses with highbush varieties gave a fruit set of from 1 to 27 per cent. Crosses with the dryland species, *V. alto-montanum* Ashe, gave 1 per cent set; but no berries matured when pollen from a selection of the lowbush (*V. lamarckii* Camp) was used (not recorded in Table II).

Vaccinium myrsinites Lam. when selfed set 79 per cent of its flowers, but when crossed with other tetraploids, a selection of the cultivated highbush (DN-76) and Orvis Williams (*V. corymbosum* L.), only about one-half of its flowers produced mature berries. When pollinated by the rabbiteye variety Owens, a fruit-set equal to that caused by self-pollination was obtained, although its fruit-set by pollen of the hexaploid *V. constablaei* was only 19 per cent. However, *V. constablaei* is more closely allied to *V. pallidum* Ait. than to the rabbiteye group.

One bush of the diploid species *Vaccinium tenellum* Aiton gave a low fruit set (29 per cent) when selfed, but when crossed with another clone of the species over 80 per cent of the flowers pollinated set fruit. A high set was obtained from an interspecific cross with *V. myrtilloides* Michx. (= *V. canadense* Kalm). Another bush of *V. tenellum* (not given in Table II) when selfed set 16 per cent of its flowers. Thus two clones of *V. tenellum* required cross-pollination for a high set of fruit.

Vaccinium darrowi Camp, a diploid evergreen species, gave a low set (15 per cent) when selfed, but approximately two-thirds of the flowers set when pollen of the diploid species *V. pallidum* and *V. elliottii* Chapman was used. These data suggest that the fruit set of *V. darrowi* may be markedly benefited by cross-pollination, but no other clone of the same species was available for testing the matter further.

Days to Maturity:—The hybrid M-29 has a long period of fruit development, more nearly comparable to that of its rabbiteye parent than to the relatively short period of its other parent, the northern highbush. However, the hexaploid, *Vaccinium constablaei* (Cov. selection), which matured its fruit in 49 days when pollinated by Myers, had a period of fruit development similar to that of the earlier ripening varieties of the northern highbush. Crossed berries of the self-sterile plant of *V. virgatum* ripened from 85 to 93 days (averages for 6 crosses) after flowering.

The crossed berries of *Vaccinium myrsinites,* all of which resulted

from interspecific pollinations, tended to ripen as early as or earlier than the selfed berries except for the 11 berries that were set with *V. constablaei* pollen. Data for time of maturity are not adequate because of the few berries harvested in this cross. The diploid species *V. tenellum* and *V. darrowi* (Table II) both ripened their crossed berries much earlier than those set by self-pollination regardless of the fact that the crosses were made in three cases with other species.

Size of Berries:—Although cross-pollination of *Vaccinium myrsinites* with other tetraploid species did not result in larger berries than resulted from self-pollination, crossing with 2 hexaploid species did result in somewhat larger berries. Berries of both *V. tenellum* and *V. darrowi* were increased markedly in size by cross-pollination as compared with self-pollination.

Seed Content:—The pentaploid selection M-29 had by far the largest berry for its seed content of any blueberry yet studied. Berries weighing 899 mg. (average weight) had but one or two plump seeds per berry.

For *Vaccinium myrsinites*, in which no significant increase in berry size (weight) was found when interspecific crosses at the tetraploid level had been made, the seed weight per berry for the crossed berries (x DN-76) was somewhat less than for the selfed berries. However, in the case where berries of *V. myrsinites* (4x) set by pollen of Owens (6x) were larger than the selfed berries the seed content of these larger, crossed berries was greater than that of the fruits from self-pollinations. On the other hand, the few relatively large berries of *V. myrsinites* set by pollen of *V. constablaei* had the lowest seed content of any berries of *V. myrsinites* either selfed or crossed. Thus in these interspecific crosses, berry size was not consistently correlated with seed content.

The diploid species had a higher seed content for crossed berries than for selfed berries, both for crosses between clons of the same species and for crosses between species.

Discussion

These results not only show some degree of self-incompatibility in most varieties of the rabbiteye blueberry and in related southern species, but also provide further evidence that in the blueberry cross-pollination frequently provides a greater stimulation to fruit development, both in size attained and in rate of ripening, than does self-pollination. A high positive correlation between berry size and seed content for the northern highbush blueberry has already been reported (4, 8, 7). This association of large size of berry with a large number of seeds, in particular with fully developed or plump seeds, may in itself be an indirect factor in the fruiting response of a variety. The pentaploid M-29 is suggestive. M-29 had only one to two plump seeds per berry when crossed with Myers but its fruit size was approximately as great as that of Myers when Myers was cross-pollinated by Owens. However, Myers had 29.5 seeds per berry. That is, it might be said that one or two fully developed seeds in berries of M-29 gave a stimulus equal to 29 to 30 seeds in Myers. While actual counts of

the original number of ovules per berry have not yet been made, it may be assumed that the numbers were approximately similar in the two sorts. Thus, while large size of berry is commonly associated with a large number of seeds, it is possible that growth stimulus that results in large early-ripening fruit is not necessarily dependent on the presence of many fully developed seeds. The fact that this large size of berry is usually associated with a large number of plump seeds per berry suggests that a hormone or hormones are activated as a result of pollination and subsequent fertilization of the ovules, such hormone or hormones being primarily responsible for the growth responses of the fruits. Possibly the greater the number of ovules fertilized, even though abortion takes place prior to full development of many of the seeds, the greater the amount of hormone substance that is released. Then in turn, the greater the amount of hormone, the larger the berry that results from fruit that has set as a result of pollination.

The blueberry is wholly insect pollinated in nature and no parthenocarpic berries have ever been noted. However, the introduction of a stimulating influence as a direct result of pollen applied to the stigma may also be a factor in setting and further development of the berry. The pollen itself may contain a growth substance or hormone that aids fruit setting and development independently of fertilization of the ovules. The marked stimulation to early maturity and large size of berries that resulted from cross-pollination may have been initially due to the increased number of developing embryos, with the developing embryos in turn influencing the amount or kind of hormone or hormones that affect berry size and rate of maturity. The stimulating agent, of course, can be effective only within the limitations of size of berry and time of maturity that are imposed by the genetical makeup of a particular variety or clone. Regardless of whether self- or cross-pollination takes place, the inherent fruiting capacity of the variety in turn is expressed only under a favorable environment.

Summary

In one year's tests under greenhouse conditions, most varieties of the rabbiteye blueberry *(Vaccinium ashei)*, including the most important commercial varieties, were either partially or completely self-unfruitful. However, one variety (Blueboy) of 10 varieties tested was completely self-fruitful. All varieties produced larger berries when cross-pollinated then when self-pollinated. The percentage increase in berry size due to cross-pollination ranged from 18 to 178 per cent for 10 varieties studied. Cross-pollinated berries also generally showed a shorter period from pollination to maturity than self-pollinated berries. Crossed berries of the variety Myers ripened on the average as much as 24 days earlier than did the selfed berries. Large size of berry was associated with a high seed content per berry.

The pentaploid hybrid M-29 (highbush x rabbiteye) was self-sterile but set over one-half its flowers when pollinated with either the hexaploid rabbiteye variety Myers or the tetraploid highbush Stanley.

The available clone of the tetraploid species *Vaccinium virgatum* was self-sterile, but a plant of *V. myrsinites* was self-fertile.

The two diploid species *Vaccinium tenellum* and *V. darrowi* gave a poor set of fruit when selfed and a much greater fruit set with cross-pollination. With the few exceptions noted herein, possibly due to the interspecific crosses involved, an increase in berry size and seed content and an earlier ripening of berries was associated with cross-pollination in the case of the tetraploid and diploid southern Vaccinium species studied as well as for the more important rabbiteye blueberry varieties.

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Improvement of the Rabbiteye Blueberry

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The rabbiteye Blueberry, native to restricted areas of north Florida, southern Georgia, and southeastern Alabama, has been planted in 3,000 to 4,000 acres of land in the same general area. Until recently nearly all plantings were of relatively unselected bushes transplanted from the wild. Many of these bear small, black, nearly inedible berries. Some bear large, good-flavored berries and a few bear light-blue fruits. Only a few acres have been planted to named varieties having relatively superior fruit qualities.

Following surveys made by Batchelor[1] to select the best rabbiteye bushes, breeding work was started, using for parents the varieties considered promising.

The merits of the rabbiteye blueberry are (a) its extreme vigor, some varieties growing to a height of 15 feet with a spread of 15 feet; (b) its drought and heat resistance in contrast to the lack of drought and heat resistance of the highbush varieties; (c) its fine scar (point of separation from the stem or pedicel), most rabbiteye varieties equaling or surpassing the best of the highbush blueberries in the character of their scar; and (a) its adaptation to the lower South because of its short rest-period requirements. Its limitations as a commercial fruit are (a) the dark-blue or black color of most named varieties; (b) the long picking season of most varieties, 30 to 90 days; (c) their late ripening, ripening and competing with the early highbush varieties in North Carolina; and (d) their relatively large seeds and the seediness of the varieties. However, some varieties have fine, light-blue fruit, some a short ripening season, some are fairly early, and their seed size is variable.

This paper is a first report on the cooperative work covering tests of the first crosses. The crosses were made at Beltsville, Maryland, in 1940 and the seedlings raised there in the winter of 1940–41. The seedlings planted at Beltsville and at Ivanhoe, North Carolina, were set in the spring of 1941; those at Tifton, Georgia, were set in November 1941.

At Beltsville, Maryland, in January 1943 a temperature of about −17 degrees F 2 feet from the ground killed the fruit buds on all seedlings and injured some young shoots on some bushes. A temperature of about −1 degree in January 1944 may have injured some fruit buds. Some seedlings bore a good crop in 1944, though most had few or no berries.

At Ivanhoe, North Carolina, of 425 rabbiteye seedlings, 305 had fruit enough for sampling in 1943. In 1943 and again in 1944 late

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[1] J. M. Batchelor, formerly associate horticulturist of the U. S. Soil Conservation Service, now in the U. S. Army, made extensive surveys of the rabbiteye blueberry in Florida, Georgia, and adjacent States during the years 1939–41 and kindly made his results available to the authors.

frosts reduced the crop on most seedlings so that only tentative selections were made. Records given in Table I for Ivanhoe, North Carolina, were taken July 5 and 6, 1943, at about the height of the season. Frequent rains, with a relatively light crop, caused the berries to be of good size.

TABLE I—SUMMARY OF SOME CHARACTERISTICS OF BLUEBERRY CROSSES AND OF THEIR PARENTS, TIFTON, GEORGIA, AND IVANHOE, NORTH CAROLINA

PART 1—RATING OF SEEDLINGS 1943 AND 1944

Cross	Number Plants	Fruit Color, Rating 5 or more (Per Cent)	Plant Vigor of 8-10 (Per Cent)	Spot Resistance of 8-10 (Per Cent)	Mildew Resistance of 8-10 (Per Cent)	Berry Diameter 15 Mm or More (Per Cent)	Number Selections	Cup Count Average of 10 Seedlings, 1944
				Tifton, Georgia				
Black Giant × Hagood	16	0	69	56	75	7	0	—
Suwanee × Black Giant	113	14	76	76	21	21	11	164
Myers × Black Giant	251	25	82	73	21	13	18	194
Suwanee × Hagood	54	9	83	78	22	4	4	215
Hagood × Black Giant	18	0	89	39	61	19	0	173
Hagood × Clara	5	0	80	60	40	0	0	181*
				Ivanhoe, North Carolina				
Black Giant × Long	27	0	31	100	100	14	—	—
Black Giant × Hagood	32	0	15	84	100	30	—	—
Hagood × Long	36	0	20	100	100	4	—	—
Suwanee × Black Giant	24	4	7	89	95	10	—	—
Myers × Black Giant	64	17	41	84	99	39	—	—
Black Giant × Clara	21	0	23	92	96	21	—	—
Myers × Ruby	51	39	12	55	100	16	—	—
Myers × Clara	49	41	38	83	100	14	—	—

PART 2—RATING OF BLUEBERRY VARIETIES USED AS PARENTS, TIFTON, GEORGIA—1943**

Variety		Color Rating		Plant Vigor	Spot Resistance	Mildew Resistance		Cup Count**
		Leaf	Fruit					
Suwanee	—	4	4	8	—	9	—	216
Black Giant	—	2	2	10	0	10	—	158
Myers	—	4	5	9	—	7	—	172
Hagood	—	2	3	10	—	10	—	191
Clara	—	6	5	8	—	9	—	191
Ruby	—	5	5	7	—	10	—	128

*Average of five seedlings.
**Cup count of varieties for 1944.

At Tifton, Georgia, 756 seedlings of rabbiteye crosses were set, and 481 were alive when the records were taken. A severe drought in 1942, before the plants were deeply rooted, caused most of the losses. Though unusually late frosts occurred in 1943, the rabbiteye varieties produced good crops and over 80 per cent of the seedlings fruited.

Some had a quart or more of fruit and many of the bushes were 3 to 4 feet high. Records were taken June 22, 1943, and June 19 to 24, 1944,[2] at about the height of the picking season for varieties. In 1944 all plants fruited, some bushes producing more than 10 quarts. The average height of the plants was about 4.5 feet, though some were over 6 feet tall. Severe droughts in both 1943 and 1944 reduced the size of the berries considerably.

A rating system was used for taking records, each of several characteristics being scored from 1 to 10, with 10 as the highest score. The most vigorous plant, the most glaucous leaf, the bluest berry, the earliest to ripen, and the greatest resistance to leaf spot and to mildew on the leaves were each given a rating of 10. Except for season of ripening, a rating of 5 was considered the lower limit of desirability in any characteristic. Some late-ripening selections were made with the idea of extending the ripening season throughout the summer. A color rating of 5 was considered equal to the usual color of the Weymouth variety. No selection with a rating for vigor of less than 7 was made.

Of the 23 selections at Tifton, Georgia, 22 had a fruit-color rating of 5 or above; in 1944, 4 had berries with a count of 79 to 96 per half-pint cup, which was much larger size than any named rabbiteye variety in the planting. (A cup count of 90 or less is required for the best grade of the highbush varieties). For mildew resistance, 16 selections had a rating of 8 to 10, and 30 were rated 8 to 10 on resistance to leaf spot. On June 20, 1944, 16 seedlings had not ripened any berries, while 49 seedlings were relatively early (rating 8–10 for season, or as early as the Jersey or Rubel highbush varieties).

A notable characteristic of the rabbiteye blueberry is the high correlation between glaucousness of leaf and blueness of berry. Every bush with a blue berry was found to have a glaucous leaf. If all seedlings with shiny foliage had been discarded, not one blue-fruited seedling would have been discarded. In general, the more glaucous the leaf the bluer the berry. At Tifton, Georgia, 13 per cent (see Table I) of Suwanee x Black Giant, 25 per cent of Myers x Black Giant, and 9 per cent of the Suwanee x Hagood seedlings had ratings for fruit color of 5 or above, while none of the seedlings of crosses between Hagood and Black Giant had a color rating even as high as 4. At Ivanhoe, North Carolina, 41 per cent of the Myers x Clara (blue x blue), 39 per cent of the Myers x Ruby (blue x blue), 17 per cent of the Myers x Black Giant (blue x black), and 4 per cent of the Suwanee x Black Giant (blue x black) had a fruit color rating of 5 or above. For all crosses at both locations the average for the blue x blue crosses was 40 per cent blue-fruited, and for the black x blue crosses, 18 per cent blue-fruited. In this first lot of rabbiteye seedlings it seemed desirable to save some selections with a color rating as low as 1 to 4 for further testing and for use in breeding.

[2]F. L. O'Rourke, junior plant propagator, U. S. Soil Conservation Service, while at Tifton, Ga., in 1943, and S. A. Harmon, assistant horticulturist, Georgia Coastal Plain Experiment Station, in 1944 kindly assisted the writers in taking the records.

However, hereafter only some 40 per cent (see Table II) of the most glaucous seedlings where both parents are glaucous, and only 18 per cent of the most glaucous seedlings of the glabrous x glaucous progenies would need be fruited. No crosses between 2 black-fruited varieties have given any blue-fruited seedlings.

TABLE II—RATINGS OF SEEDLINGS OF BLUEBERRY CROSSES FOR COLOR OF FRUIT AT IVANHOE, NORTH CAROLINA AND TIFTON, GEORGIA 1943 AND 1944

Progeny	Number of Plants	Parental Fruit Color Rating	Plants in Each Color Class (Per Cent)			
			1–2	3–4	5–6	7–8
Rabbiteye Crosses						
Black Giant × Long (N. C.)	27	2 × 2	100	0	0	0
Black Giant × Hagood and reciprocal (Ga. and N. C.)	66	2 × 3	73	27	0	0
Hagood × Long (N. C.)	36	3 × 2	95	5	0	0
Suwanee × Black Giant (Ga. and N. C.)	135	4 × 2	49	39	11	1
Suwanee × Hagood (Ga.)	54	4 × 3	46	45	9	0
Myers × Black Giant (Ga. and N. C)	313	5 × 2	46	30	24	0
Black Giant × Clara (N. C.)	21	2 × 5	62	38	0	0
Myers × Ruby (N. C)	51	5 × 5	43	18	39	0
Myers × Clara (N. C.)	49	5 × 5	39	20	37	4
Summary for Rabbiteye Crosses						
Black × black	129	——	83	17	0	0
Black × blue	523	——	48	34	18	0
Blue × blue	100	——	41	19	38	2
Highbush × Lowbush (North Carolina)						
Weymouth × Mich. L B. No. 35*	39	5 × 8	57	41	2	9
Weymouth × Mich. L.B. No. 1*	22	5 × 8	36	55	9	0
Dixi × Mich. L.B. No. 1*	64	6 × 8	0	50	50	0
Dixi × AH-78*	96	6 × 4	0	1	77	22

*L. B. No. 1 and L. B. No 35 refer to 2 lowbush selections from Michigan, while AH-78 refers to a selection of Allen (lowbush) × GM-37 (highbush).

For comparison records on crosses between the highbush and lowbush at Ivanhoe, North Carolina, are also given in Table II. Where the highbush parent (Weymouth) had a dark blue fruit color, the seedlings were nearly all dark, but when the highbush parent (Dixi) was a medium blue many of the seedlings were medium blue. When the highbush (Dixi) was crossed with a selection of highbush x lowbush (AH–78) 99 per cent were medium to light blue in color.

The ratings for vigor were generally high, and higher at Tifton, Georgia, than at Ivanhoe, North Carolina. For example, for the 3 crosses represented at both places in 1943, 60 per cent were rated 8 to 10 in vigor at Tifton and only 21 per cent at Ivanhoe. Apparently a considerable proportion are better adapted to the climate or soil at Tifton than at Ivanhoe. However, even at Ivanhoe most of the seedlings are more vigorous than progenies of the northern highbush crosses near by.

Mildew was epidemic at Tifton, and a leaf spot was epidemic at Ivanhoe. Certain crosses at each place were highly resistant under the weather conditions prevailing, while other crosses were quite susceptible to these diseases.

Because of the drought in 1943, at Tifton a smaller percentage of the seedlings had berries 15 mm or over in diameter there than at Ivanhoe. Only two or three small-fruited seedlings were noted in either planting. Some selections at both Tifton and Ivanhoe had cup counts well under 100 per cup and compare with the large fruited highbush in average size of berry. In the very dry season of 1944, four selections at Tifton had counts of 79 to 96 berries per cup, eight selections had counts of 103 to 127, eleven selections had counts of 130 to 158, and three selections had counts of 165 to 188. In general, the rabbiteye varieties hold up in size through the season better than do the highbush sorts.

Mulch Versus Clean Cultivation as Affecting Vineyard Performance

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The use of mulch as a means of conserving soil moisture and controlling erosion in vineyards has been suggested as a worthwhile practice but little appears to have been written on the influence of mulches on vine performance.

To test the practical value of such treatment an experiment was set up at the Plant Industry Station, Beltsville, Maryland, in the fall of 1937, using for the purpose the own rooted vines of Concord, Ontario, and Delaware varieties that had served as buffers in the rootstock test vineyard. Mulched and clean-cultured rows alternated in the test. One hundred and twenty vines of each variety entered into the test, 60 mulched and 60 given clean cultivation. Units of six vines of each variety arranged in the order indicated were replicated five times in each of two mulched and of two clean-cultivated rows. In this case the grafted vines of the rootstock test served as buffers. The vines of the two series were paired except for an occasional vine that had failed. These instances will be considered presently.

The mulch used was of corn stover of the current season's growth renewed annually and applied to a depth of 6 to 8 inches and a width of 18 to 24 inches on either side of the vines in the row.

Clean culture consisted in the use of the single-horse cultivator and of hand hoes near the vines, and the disc harrow in the space between the test and adjacent buffer rows. The ground cover of the mulched rows consisted of a thin stand of weeds and grass kept low by occasional mowing. Half the vines received 1 pound of nitrate of soda in the spring shortly after the growth started and the other half received ¾ pound per vine of 5–8–5 commercial fertilizer. This was broadcast at a radius of about 3 feet about the base of the vines. The treatment was uniform for both mulched and clean-cultured vines.

In the case of the Concord variety the stand of vines was complete. With the Ontario, one vine in the clean cultivation series and three in the mulched series were lacking, and in the calculations on which the following table is based a weight value equal to the average of all the other vines in the series was given for these missing vines. The same method was followed with missing vines of the Delaware variety, of which there was one in the clean cultivation group and six in the mulched series.

Yields of fruit and of wood are based on the 5-year average performance of the individual vines. In addition, the total dry matter produced under the two treatments is given. The experimental data are presented in Table I.

These data show that with clean cultivation the Concord grape vines in this test yielded over 67 per cent, Ontario 100 per cent, and Delaware over 22 per cent more fruit than with the corn-stover mulch. The amount of wood growth with all three varieties was consistently

TABLE I—SUMMARY OF FINDINGS ON THE COMPARATIVE EFFECTS OF CLEAN CULTIVATION VERSUS CORN STOVER MULCH ON YIELDS OF FRUIT, WOOD, AND TOTAL DRY MATTER OF CONCORD, ONTARIO, AND DELAWARE GRAPE VINES†

Treatment	Fruit (in Ounces)			Wood (in Ounces)‡			Dry Matter (in Ounces)§		
	Mean	Difference of Means	Standard Error of Difference	Mean	Difference of Means	Standard Error of Difference	Mean	Difference of Means	Standard Error of Difference
				Concord					
Clean cultivation	179	—	—	57	—	—	106	—	—
Mulch	107	72**	7.1	67	10	4.0	82	24**	4.3
				Ontario					
Clean cultivation	140	—	—	29	—	—	74	—	—
Mulch	70	70**	7.5	33	4	1.9	48	26**	3.9
				Delaware					
Clean cultivation	208	—	—	51	—	—	115	—	—
Mulch	170	38*	11.7	56	5	4.1	102	13	6.7

*Significant.
**Highly significant.
†Based on results with 120 vines of each variety—60 vines for each treatment. Yields of fruit and wood based on a 5-year average of each vine.
‡Fresh-weight basis.
§The dry weight in the case of fruit was taken as 42 per cent of the fresh weight, this value being derived from the published tables of Atwater and Bryant (Ref. 1). In the case of wood 54.6 per cent of the fresh weight was used, this figure having been determined during the present investigations.

slightly higher where the mulch was applied, but not significantly so. In the case of total dry matter both the Concord and Ontario varieties produced very significantly greater amounts with clean cultivation, but with Delaware the higher production under clean cultivation was hardly significant.

The reason fruit production should have been so much heavier under clean cultivation is not entirely clear. It is true that there was a tendency for the mulched vines to show more vegetative activity but this did not appear great enough to account for the pronounced differences in fruit production. It is possible that mulches of other sorts would have given different results, but so far as known to the writers there is no constituent of corn stover that should be inimical to fruitfulness of horticultural crops.

The experimental data were carefully analyzed to determine whether there were differences in the performance of vines under the two fertilizer treatments. No advantage whatever was found for one fertilizer treatment over the other as indicated by either fruit or wood production.

One other consideration in connection with the use of mulches in vineyards should be mentioned; namely, the shelter it gives to overwintering insect pests. While no figures were recorded in these experiments to confirm it, it was notable that during the period of the present study there was a progressive increase in the berry moth infestation of fruit even though careful spraying for its control was consistently practiced. In other vineyard units where wheat and rye straw mulches were used it was found necessary to abandon their

use and return to clean cultivation in order to keep down the overwintering insect populations.

It is of interest to note that although the Delaware variety has been generally considered a weak-growing and low-yielding grape it consistently out-yielded both the Concord and Ontario varieties in these tests in both wood and fruit.

The evidence here presented indicates that from the standpoint of the fruit production and the welfare of the vineyard, clean cultivation is preferable to the use of corn stover mulch.

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Fertilizer Requirements of Strawberries on New Land in North Carolina[1]

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Strawberry production requires more man hours per acre than does any other crop grown in North Carolina (3, 12). Since newly cleared land is comparatively free from weeds and grass for the first two or three years of cultivation, many growers have resorted to its use wherever possible as a means of reducing labor in strawberry production. However, low yields frequently result from the use of new land. Lineberry and Collins (8) reported increased yields on new land from the use of phosphate and limestone. Clark (1) in 1941 reviewed the literature on strawberries, but no adequate information was available regarding fertilization on new land.

To obtain more complete information upon the fertilizer requirements of strawberries on new land in the Coastal Plain, the experiments reported herein were undertaken to study the effect of sources and levels of nitrogen and levels of phosphate, potash, and limestone on strawberry production.

Experimental Procedure

Soil:—A Coxville fine sandy loam soil was selected as typical of strawberry soils in eastern North Carolina. The soil was relatively high in organic matter. Before clearing, pine trees had dominated the timber growth. The land was cleared in the winter, disked, and fallowed during the following summer. In the fall it was disked again and thoroughly cultivated.

Before any fertilizer was applied, the soil had a pH of 4.60, and base exchange properties as follows: Total base exchange capacity, 22.0 m.e.; exchangeable hydrogen, 20.6 m.e.; exchangeable calcium, 0.54 m.e.; exchangeable magnesium, 0.23 m.e.; and exchangeable potassium, .23 m.e.

Materials and Field Plan:—The nitrogen in the NPK experiment was derived from four sources as follows: sodium nitrate, ammonium sulphate, urea, cottonseed meal, and a mixture of one-fourth each. Each source was used at three rates, namely, 60, 100, and 140 pounds of N per acre, either alone, or with 160 pounds of P_2O_5 per acre, or with 120 pounds of K_2O per acre, or with 160 pounds of P_2O_5 and 120 pounds of potash per acre. The P_2O_5 was derived from 20 per cent superphosphate and the K_2O from muriate of potash. There were two replicates of the 60 treatments arranged in a split block design.

Before the plants were set, dolomitic limestone was applied at the

[1]Contribution from the Department of Agronomy, North Carolina Agricultural Experiment Station, and the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture. Published with the approval of the Director as paper No. 190 of the Journal Series.

rate of 1000 pounds per acre to each row in a furrow 6 inches deep in a strip about 6 inches wide. Plants of the Klondike variety were set in February, 1941, on a ridge approximately 8 inches high. Half of the fertilizer was applied in the following September in two bands 6 inches from the center of the row, 5 inches deep. The other half was applied in December on top of the row and brushed off.

A limestone experiment was started 1 year later on adjoining land of similar soil characteristics. The land was prepared as described for the NPK experiment except that no limestone was applied under the plants before setting. A 4–8–4 fertilizer was used, the nitrogen being derived one-fourth each from sodium nitrate, ammonium sulphate, urea, and cottonseed meal. The rate of application and placement was as indicated in the NPK experiment. The limestone was applied at rates of 1 and 2 tons per acre. It was broadcast on top of the soil and disked in to a depth of 5–6 inches.

Soil Analysis:—The pH of the soil was determined with a pH meter using the glass electrode. The base exchange properties of the soil were determined by the procedure of Mehlich (10).

Leaf Analysis:—The soluble nutrients in the leaf were extracted by boiling with water for 30 minutes. The total nutrients were determined by igniting the dried leaf in an electric furnace and dissolving the ash in dilute acid. The minerals in the solutions from these two treatments were determined by usual laboratory procedure.

Results and Discussion

Effect of Nitrogen and Phosphate:—Nitrogen, when used alone or in combination with 120 pounds of potash, produced but little plant

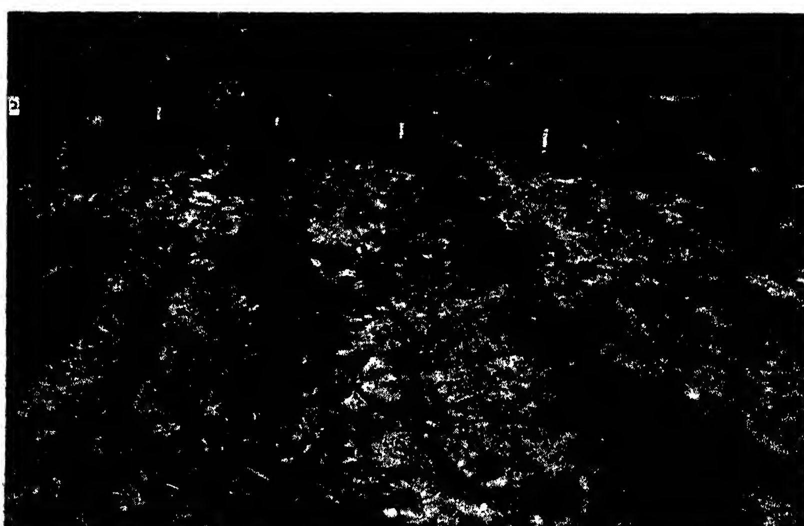

FIG. 1. Effect of phosphate on plant growth on new land. In the foreground 3–0–6 fertilizer was applied; beginning at stakes 3–8–6 fertilizer was applied.

growth or runners. However, the addition of 160 pounds of P_2O_5 to the fertilizer resulted in an increase of 70 per cent in fresh weight of mature leaves when measured in the fall, and a 320 per cent increase in total fresh weight of plant when measured at the end of the harvesting season. (See Fig. 1.)

Without phosphate, the mother plants developed very little. The young leaves were small, thin, and very dark green; and very few runners ever developed. As the leaves reached maturity the blades became bronzed and purple, with the midribs and veins of the under surfaces also purple. This agrees with the descriptions of phosphate-deficient plants reported by Davis and Hill (2), Hoagland and Snyder (4), and Lineberry and Burkhart (5).

However, plants receiving cottonseed meal but no superphosphate made far better growth (Fig. 2) than plants receiving nitrogen in the other three nitrogen carriers. This better response with cottonseed meal was probably due to the 2.5 per cent P_2O_5 it contained.

Average yields of fruit for the duplicate plots of each treatment in the spring of 1942 are shown in Fig. 3. Where the fertilizer did not contain any phosphoric acid, either as superphosphate or in cottonseed meal, yields were relatively low (about 2,000 quarts per acre); but

Fig. 2. The effect of cottonseed meal on plant growth. (No. 7) 7–0–6 nitrogen derived from cottonseed meal; (No. 8) 7–0–6 nitrogen derived from urea.

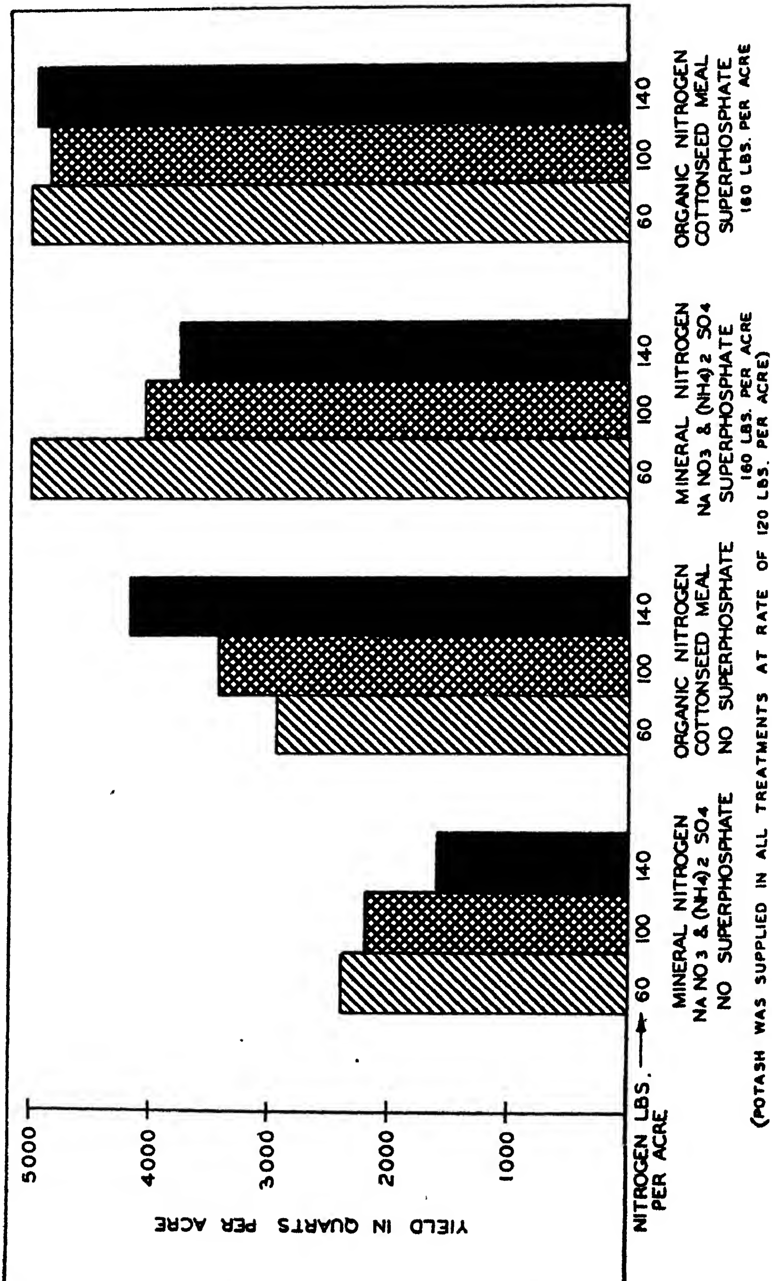

FIG. 3. Effect of sources and rate of nitrogen on yields of strawberries on new land without and with superphosphate.

satisfactory yields (4,000 quarts or more per acre) were obtained where the fertilizer contained 160 pounds of P_2O_5. The effect of the cottonseed meal in increasing the yield over other sources of nitrogen, when used alone or with potash, was outstanding. This was especially true at the two higher rates of nitrogen application. Presumably this was true because of the increased amount of phosphoric acid applied with the greater quantities of cottonseed meal necessary to provide the larger amounts of nitrogen.

In complete fertilizers, the three per cent level of nitrogen from $NaNO_3$, $(NH_4)_2SO_4$, and urea gave significantly higher yields than did the five and seven per cent levels. High nitrogen from these sources produced excessive plant growth (Fig. 4) with a corresponding decrease in yield. The data would seem to indicate that 60 to 100 pounds of nitrogen per year would be sufficient for satisfactory production. In the case of cottonseed meal the five and seven per cent nitrogen levels did not materially decrease yields.

Ammonium sulfate as the source of nitrogen resulted in about the same yields as did sodium nitrate or urea, even though several investigators have reported the indirect effect of the type of nitrogen carrier in changing the acidity of the soil. Morris and Crist (11) and Lineberry (6) found ammonium sulphate to decrease plant survival due to increased acidity of the soil. Clark (1) obtained the best growth

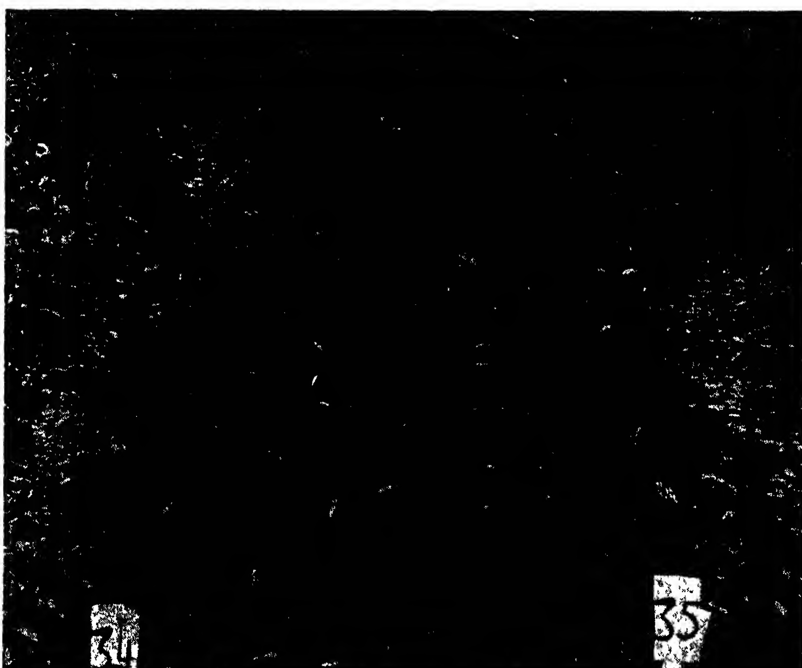

FIG. 4. Vigorous plant growth resulting from the use of high-nitrogen fertilizer, which was associated with lowered yields. (No. 34) 7–8–6, nitrogen derived from sodium nitrate; (No. 35) 7–8–7, nitrogen derived from urea.

from nitrate nitrogen at pH 4.6 and from ammonium nitrogen at pH 6.4. However, in the experiment reported here, no differences were found in the effect of different sources of nitrogen which could be attributed to changes in the acidity of the soil. This was probably due to the limestone applied at the beginning of the experiment.

TABLE I—EFFECT OF NITROGEN LEVEL AND SOURCE ON THE YIELD PER ACRE OF STRAWBERRIES, WITH AND WITHOUT SUPERPHOSPHATE

Nitrogen Sources	No Superphosphate			160 Pounds of Superphosphate Per Acre		
	Nitrogen Per Acre (Pounds)			Nitrogen Per Acre (Pounds)		
	60	100	140	60	100	140
	Qts	Qts	Qts	Qts	Qts	Qts
$NaNO_3$	2,170	1,974	1,901	5,423	4,067	3,880
$(NH_4)_2SO_4$	2,368	2,138	1,300	4,800	4,090	3,844
Urea	2,724	2,405	1,535	5,158	4,580	4,038
Cottonseed meal	2,600	3,757	4,407	4,799	4,666	4,703
¼ of each of the above sources	2,443	2,418	2,057	6,031	4,860	4,560

Effect of Potash:—The addition of potash to the nitrogen fertilizer or to the mixture of nitrogen and phosphate fertilizer had no consistent effect on yields. The growth was apparently normal and no potash deficient symptoms were observed in the plants not receiving potash fertilizer. This would seem to indicate that this new land supplied sufficient available potash for the first fruiting of strawberries, and that the strawberry plant may be an efficient extractor of potash from the soil due to continued root growth throughout the entire winter under North Carolina conditions (8) and to the high potash content of the roots in the winter in comparison to other parts of the plant (9).

Effect of Limestone:—One ton of limestone applied in the fall of 1942 significantly increased the yield over no limestone in the 1943 fruiting season (Table II). However, two tons did not significantly increase the yield over one ton; although, as shown in Table III, the pH was increased from 4.75 for one ton to 5.30 for two tons, the exchangeable calcium from 1.14 m.e. to 3.48 m.e., and the exchangeable magnesium from 0.80 m.e. to 1.50 m.e.

TABLE II—EFFECT OF LIMESTONE APPLIED 18 MONTHS PREVIOUS ON YIELD AND ON MINERAL COMPOSITION OF MATURE LEAVES SAMPLED IN JUNE, 1943. MINERAL COMPOSITION EXPRESSED ON A DRY-WEIGHT BASIS

Treatment	Yield Per Acre (Quarts)	K_2O (Per Cent)	PO_4 (Per Cent)	CaO (Per Cent)	MgO (Per Cent)
No lime	1,442	1.90	0.44	1.18	0.70
1 ton	2,160	1.60	0.43	1.43	0.80
2 tons	2,286	1.50	0.43	1.48	0.86
L.S.D. (.05)	343.2	0.091	—	0.076	0.050
(.01)	467.4	0.137	—	0.115	0.076

Further experimental work is necessary to attempt a full explanation as to why additional limestone did not increase the yield. It is

TABLE III—EFFECT OF LIMESTONE ON THE pH AND BASE EXCHANGE PROPERTIES OF COXVILLE FINE SANDY SOIL

	Treatment		
	No Lime	1 Ton	2 Tons
Date sampled	Dec 1, 1941	Jul 1, 1943	Jul 1, 1943
pH value	4.42	4.75	5.30
Total base exchange capacity (m.e.)	22.9	22.1	22.1
Exchangeable hydrogen (m e.)	20.6	20.0	16.6
Exchangeable calcium (m.e.)	0.50	1.14	3.48
Exchangeable magnesium (m.e.)	0.29	0.70	1.50
Calcium saturation (percentage)	2.2	5.2	15.7
Calcium plus magnesium saturation (percentage)	3 5	8.3	22.6

suggested that since the limestone was applied in a zone 5–6 inches deep, one ton of limestone satisfied the requirements of strawberries in that zone at least for one year. Since the calcium ion is rather immobile. the effects of limestone were confined to 5–6 inch zone as the root system was largely in this area. Below the 6-inch depth, the pH was 4.42 which explains why there was no root penetration into this zone. This is substantiated by the findings of Lineberry (6), which indicate that strawberries will not live in a medium below a pH of 4.50, and the deficiency studies of Lineberry and Burkhart (7) showing that without calcium there was no root development in strawberries.

EFFECT OF FERTILIZER ON LEAF COMPOSITION

Nitrogen, Phosphoric Acid, and Potash Experiment:—In view of the striking response of strawberries to phosphoric acid, and the lack of response to potash, it appeared that if the phosphorus, potash, calcium, and magnesium content of the leaf were known, the grower would have a better understanding of the probable effect of fertilizer on plant growth and yield.

To ascertain the proper age of leaves for sampling, mature, young, and runner leaves were taken from the 5–8–6, 5–8–0, and 5–0–6 treatments. Three samples of 100 leaves each were taken from every plot and the minerals were extracted by boiling in water for 30 minutes and determined by the usual laboratory methods. In later experiment, the material was ignited and the minerals determined in the ash, which method gave about the same magnitude of difference in mineral content as did the boiling water extraction.

Both the mature and the young crown leaves showed relatively low P_2O_5 and K_2O content where phosphorus and potash, respectively, were omitted from the fertilizer, indicating that these two leaf types may be expected to show nutrient deficiency (Table IV). From the standpoint of obtaining leaf samples in the field, it was impossible during the summer to select runner leaves on runners of the same age, and no runner leaves are available in the winter. It was also difficult to select young crown leaves of the same age. Therefore, fully expanded, mature leaves appeared to be the most suitable for determining nutrient deficiency by foliar analysis.

It is evident from Table V that the much lower yield of fruit with 5–0–6 fertilizer than with the 5–8–6 or the 5–8–0 fertilizer was asso-

TABLE IV—MINERAL CONTENT OF THREE TYPES OF STRAWBERRY LEAVES, SAMPLED IN JUNE, 1942. FRESH TISSUE EXTRACTION; MINERAL CONTENT EXPRESSED AS PER CENT DRY WEIGHT

Treatment	Type of Leaf	CaO (Per Cent)	K_2O (Per Cent)	MgO (Per Cent)	PO_4 (Per Cent)
5-8-6	Mature leaf	0.40	1.53	0.24	0.30
	Young leaf	0.25	1.58	0.19	0.54
	Runner*	0.19	2.14	0.18	0.45
5-8-0	Mature leaf	0.43	1.34	0.34	0.30
	Young leaf	0.28	1.39	0.28	0.52
	Runner	0.26	2.14	0.22	0.46
5-0-6	Mature leaf	0.30	1.39	0.17	0.16
	Young leaf	0.23	1.80	0.18	0.26
	Runner	0.21	2.18	0.17	0.31

*Runner as here used includes both runner tip and leaf.

ciated with a much lower P_2O_5 and CaO content of the mature leaves. Omission of potash from the fertilizer resulted in a lower K_2O content of the leaves, but, as mentioned before, even at the low K_2O level (1.42 per cent of dry matter), the yield was practically as great as where potash was applied. Apparently the higher K_2O content of the leaves where potash was included represents a luxury intake of potassium by the strawberry plant, and was not definitely associated with yield under the conditions of these experiments.

TABLE V—MINERAL CONTENT OF MATURE STRAWBERRY LEAVES IN JUNE, 1942, IN RELATION TO YIELD RESPONSE TO PHOSPHORUS AND POTASSIUM IN FERTILIZER APPLIED TO NEW LAND DURING THE PREVIOUS FALL AND EARLY WINTER

Type of Fertilizer Applied in Fall, 1941	Yield of Fruit Per A in Spring of 1942 (Quarts)	Mineral Content of Mature Leaves Expressed in Percentage of Dry Weight			
		P_2O_5	K_2O	CaO	MgO
5-0-6	2,418	0.45	1.90	1.22	0.97
5-8-0	4,266	0.64	1.42	—	—
5-8-6	4,360	0.68	1.82	1.40	0.98
L.S.D. (.05)	1,900	0.023	0.134	0.086	—
(.01)	2,479	0.054	0.330	0.198	—

Limestone Experiments:—The geater yield with 1 ton of limestone was accompanied by an increased CaO and MgO content of the leaves as compared with no lime (Table II). Two tons did not materially increase the CaO and MgO content over 1 ton. The K_2O content of the leaves was decreased by the application of limestone, which agrees with the findings of Davis, *et al.* (2).

SUMMARY

1. Nitrogen fertilizer alone or with potash did not give sufficient plant growth for satisfactory yields of strawberries on newly cleared land of Coxville fine sandy loam.

2. The application of 160 pounds of P_2O_5 per acre, with nitrogen or with nitrogen and potash, resulted in satisfactory plant growth and

fruit production in the first fruiting year, in contrast to very poor growth without P_2O_5.

3. Nitrogen applied at the rate of 60 pounds per acre gave the highest yields. Higher applications of 100 and 140 pounds per acre gave excessive plant growth and lower yields.

4. The application of cottonseed meal resulted in greater plant growth and yields than other nitrogen carriers when used without superphosphate, apparently because of the phosphate content of the cottonseed meal.

5. Where the phosphate and lime requirements were supplied, there was very little practical difference between the nitrogen sources. This would indicate that the more economical sources could be used satisfactorily.

6. One ton of dolomitic limestone increased the soil pH from 4.42 to 4.75, the exchangeable calcium from .50 to 1.14 m.e., the exchangeable magnesium from .29 to .70 m.e. These changes were associated with significant increase in growth and yield.

7. The pH, the exchangeable calcium, and the exchangeable magnesium were further increased by the application of the second ton of dolomitic limestone; however, these changes were not associated with increased growth or yield.

8. Leaves showing phosphate deficiency symptoms from plants receiving no phosphate fertilizer contained 0.45 per cent P_2O_5 on dry weight basis. Leaves from plants receiving phosphate fertilizer contained 0.68 per cent P_2O_5.

9. The application of potash did not result in any increased growth or yield. However, 120 pounds of K_2O increased the potash content from 1.4 to 1.8 per cent dry weight, in the mature leaves at the end of the harvest season.

10. One ton of limestone increased the CaO and MgO content of the leaves but decreased the potash content.

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Influence of Growth-Regulating Chemicals on Blackberry Fruit Development

By Paul C. Marth and E. M. Meader, *U. S. Plant Industry Station, Beltsville, Md.*

A number of investigators (1, 2, 4, 5, 6, 7, 9, 10, 11, 12) have applied growth-regulating substances or so-called "hormones" to the flowers of crop plants to induce parthenocarpy, to prevent flower abscission, or to increase the development of edible fleshy fruit parts. As experimental work continues additional plants are gradually added to the list of those that respond favorably to treatment. This report is concerned with preliminary trials of "hormone" sprays on blackberry at two stages of flowering.

The kinds and concentrations of "hormones" applied to the blackberry were selected on the basis of their stimulatory effects in the greenhouse at Beltsville, Maryland, when used on flowers of one or more of the following plants: tomato (5), lima bean, eggplant, cucumber, strawberry, blueberry, and blackberry.

Materials and Methods

Plant Material:—The 4-year-old blackberry plants used had been propagated by root cuttings and tip layering from one seedling, U. S. D. A. No. 28, which had been selected from a cross of the Himalaya and the Oregon Evergreen varieties. Under cultivation at Beltsville, Maryland, the No. 28 blackberry produces a vigorous, free-growing, semi-erect type of bush with an abundance of clusters of large pink flowers from canes of the previous season's growth. While a detailed study of its fruit setting has not been made, some of its flowers have shown a certain degree of sterility or failure to set in some years.

Because halves of the same plant seemed more validly comparable than different plants, one-half of the total number of canes on each plant was treated, with the remaining canes on the respective plants serving as controls. When the treatments were applied, a large piece of cardboard was used to deflect the "hormone" sprays from the control half of each plant. Two rows of 50 plants each (planted 5 feet apart in the row) were so treated, using five to seven plants per treatment. The west side of the plant was sprayed in all cases. In addition, 10 plants in an adjacent row were left untreated.

On May 26, when approximately 50 per cent of the flowers were still in the bud stage, one row of 50 plants was sprayed. Eleven days later, on June 6, when approximately 5 per cent of the flowers remained unopened and many of the early-opening flowers had developed small green berries, the other row was sprayed. Each chemical applied will be referred to subsequently by the designated symbols: Indoleacetic acid, IAC; Indolebutyric acid, IBC; B-naphthoxyacetic acid, NXY; 4-chlorophenoxyacetic acid, 4-cl. Both aqueous and aerosol sprays in the concentrations listed in Table I were used.

TABLE I—EFFECT OF "HORMONE" TREATMENTS OF BLACKBERRY FLOWERS ON SUBSEQUENT FRUIT AND SEED DEVELOPMENT, BELTSVILLE, MD., 1944

No.	Treatments	Concentration (Ppm)	Treated May 26							Treated June 6	
			Mean Fresh Berry Wt. (Mg)	Berry Wt. Increase Due to Treatment (Per Cent)	Number Seeds Per Berry: Fully Developed	Number Seeds Per Berry: Small and Flat	Mean Weight of 100 Plump Seeds (Mg)	Seed as Percentage of Fresn Berry Wt. (Per Cent)	Moisture Content of Fresh Berries (Per Cent)	Mean Fresh Berry Wt. (Mg)	Increase due to Treatment (Per Cent)
					Water Sprays						
1	4-cl + NXY Mixture*	20	229.8	85	23 2	19.4	378.4 ±S.E. 3.5‡	4.3	—	239.9	48
1	Control	—	124.2	—	22.2	0.4	358.1 ±2.3	4.9	—	161.7	—
2	4-cl + NXY Mixture*	40	223.7	99	17.9	35 0	353 0 ±4.4	4.4	85 4	216.4	28
2	Control	–	112.3	—	15.8	0.1	362.3 ±3.3	4.9	81.5	168.8	—
3	NXY	20	197 2	43	—	—	—	—	—	203.5	53
3	Control	--	138.3	—	—	—	—	—	—	133.3	—
4	NXY	40	213 3	60	24.8	8.0	348.6 ±3.2‡	4.0	82.1	185.2	26
4	Control	—	133 6	—	24.1	0.7	306.9 ±1 1	6 3	81.6	146.7	—
					Aerosols						
5	NXY	250	197.7	44	24.4	0 4	337.0 ±4.6	4.1	82.5	180.1	26
5	Control	--	136.9	--	20.8	0.3	324.5 ±4.8	5.2	83.6	142.7	—
6	4-cl	10	199.3	53	—	—	—	—	—	181.7	25
6	Control	—	130.5	—	—	—	—	—	—	146.0	—
7	IAC	250	214.7	77	25.3	0.6	333.3 ±2.7†	4.0	—	170.9	32
7	Control	—	121 3	—	18 2	0.3	323.9 ±3.5	5.0	—	129.3	—
8	IBC	1,000	212.0	50	—	—	—	—	—	—	—
8	Control	--	141.2	—	—	—	—	—	—	—	—
9	Treatments 5, 6, 7, 8 combined	—	226.1	67	—	—	—	—	—	195.5§	47
9	Control	—	134 9	—	—	—	—	—	—	132.9	—

*Mixture of 40 per cent 4-cl and 60 per cent NXY. For meaning of symbols for materials, see text.

†Difference between treatment and control significant at 1 per cent level in "Student's" t-test for group comparisons.

‡Significant at 5 per cent level.

§IBC was omitted.

Aqueous Sprays:—The "hormone" sprays were prepared by dissolving a weighed amount of pure crystalline chemical in a small amount of 95 per cent ethyl alcohol. Then sufficient tap water with a small amount of wetting agent (Santomerse) was added to give a spray of the desired concentration of hormone. The spray was applied from a 3-gallon compressed-air hand sprayer. Although many of the leaves on the treated portion of the plants were sprayed, particular attention was given to thoroughly wetting the flower clusters.

Aerosol Sprays:—The aerosol sprays were made up in small steel cylinders (1-pound capacity) essentially according to the methods described by Goodhue (3) for the preparation of liquefied-gas insecticidal aerosols. In these studies a weighed amount of the growth-regulating chemical dissolved in a weighed quantity of cyclohexanone was drawn into a partially evacuated cylinder through an attachable funnel. Dimethyl ether (B. P. −27 degrees C), used as the liquefied-gas dispersing agent, was then forced into the cylinder already containing "hormone" and cyclohexanone by attaching it by means of a

gas-tight line to a larger heavy-walled tank of this compound. When the tank of dimethyl ether was heated slightly, the liquefied gas flowed over into the small cylinder which was placed on a spring balance for measuring a weighed amount of materials. Cyclohexanone, a mutual solvent for the hormones and dimethyl ether, was used in all the aerosols at the rate of 0.5 per cent. After attaching the spray nozzle the cylinder was ready for use. The blackberry plants were treated with the aerosols by thoroughly spraying all flower clusters. Whatever spraying of foliage ensued was only incidental. The spray nozzle of the aerosol cylinder was held approximately 10 inches away from the flowers to avoid any freezing injury due to the low temperatures caused near the nozzle by rapid expansion of the liquid dimethyl ether to a gas.

Method of Berry Sampling:—On July 10 or 12, when most of the berries in the clusters had ripened, two samples of approximately 100 berries each were taken at random from the treated and control portions, respectively, of each lot of plants. After fresh weights had been recorded, samples for three treatments (see Table I) were dried in an oven at 80 degrees C for 48 hours to determine the relative moisture content of the treated and control berries. Data on the relative number and weight of seeds per berry were obtained on the samples for five treatments. Seeds were extracted by means of a Waring Blendor according to the method described by Morrow (8) for blueberry seed. The seeds from each sample were separated into large, plump seeds containing well developed embryos, and small or flat seeds devoid of embryos. In addition, ten 100-seed samples of the plump seeds were separated out of each lot. Data for the relative weight of berry, for number of seeds per berry, and for the weight of 100 plump seeds are given in Table I.

Results and Discussion

Effects on Plants:—Moderate to severe epinasty had occurred on the canes of the treated half of each plant within 24 hours after the sprays were applied, clearly marking all treated canes. Canes of the current season's growth, vigorous, succulent, and 4 to 5 feet in length, were affected most. However, 1 to 2 weeks after treatment the affected canes had resumed a normal growth habit. No permanent effects on the leaves or flowers, such as burning, yellowing, or excessive greening, were noted as a result of any spray treatment, with the single exception of occasional flowers in the aerosol-treated lots that showed some petal browning. This appeared to be a freezing type of injury from direct contact with the vaporized solvents.

Effects on Fruit:—At harvest an increase in fruit set and berry development resulting from treatment was apparent as the ripe fruit hung in the clusters on the plants. Differences in fruit size were most striking between the treated and untreated portions of plants that had received concentrations of either 20 ppm or 40 ppm of mixture 4-cl + NXY. Many of the fruits on the treated portions of the bushes appeared to be twice the size of the control fruits. Closer inspection of

the individual fruits in treatment No. 2, which had received 40 ppm of the chemicals, showed that the berries were made up of large drupelets interspersed with numerous smaller drupelets, causing the fruits to have an irregular shape (Fig. 1). This effect on fruit shape was noticeable to a lesser degree in treatment No. 1, which had received 20 ppm of mixture 4-cl + NXY, but did not appear in any of the other treated lots.

Since the total weight of a blackberry fruit depends largely on its water content, the relative moisture content of the treated and untreated berries are of direct interest in this connection. The increase in moisture content for the treated berries of treatment No. 2 over that of the control may be related to the fact that the treated berries had a large number of small undeveloped seeds. Each of these small seeds was surrounded by fleshy pulp (Fig. 1.) of a high moisture content. Moreover, the treated berries had a larger receptacle, which likewise is high in moisture, than did the control fruits. In treatments Nos. 4 and 5 there was no appreciable difference in moisture content of the fruits compared. The increase in weight of the treated berries was chiefly due to an increased number of drupelets per berry.

Seed Development:—An outstanding difference in number of seeds per berry was found between the treated and control lots of berries in treatments Nos. 1 and 2 (see Table I). The total number of seeds per berry (fully developed plus small flat seeds) was increased two to three times as a result of treatment. Since each seed is contained in an individual drupelet, the total number of drupelets per berry was increased likewise. Moreover, the number of fully developed seeds was almost identical in both the treated and untreated berries. Thus the increase in seeds per treated berry consisted of numerous small, flat seeds that were stimulated to develop following flower treatment. This relative increase in seed development would suggest that the treated berries might be objectionably seedy to the consumer. However, due to the over-all berry enlargement, including the receptacle, found in the treated lots, the treated berries were actually less seedy than the control berries when eaten. When the weight of seeds per berry was expressed as a percentage of the fresh-berry weight, all treatments had a relatively lower seed content than did the controls.

In the aerosol treatments Nos. 5 and 7, there was an apparent increase in the number of plump seeds per berry without an appreciable change in the number of small flat undeveloped seeds.

The weight of 100 plump seeds from the treated fruits of treatments Nos. 1, 4, and 7, but not Nos. 2 and 5, was significantly greater (even though only 6, 14, and 3 per cent, respectively) than that of the control fruits. Thus, the over-all berry enlargement due to treatments included a slight effect on the plump seeds in several treatments as well as on the receptacle and fleshy parts of the drupelet that surrounded the seed.

Effect of Compounds and Concentrations:—Although this experiment was primarily designed to determine if the blackberry might respond to "hormone" application, rather than to establish the optimum concentration of the most effective compound, the results indicate

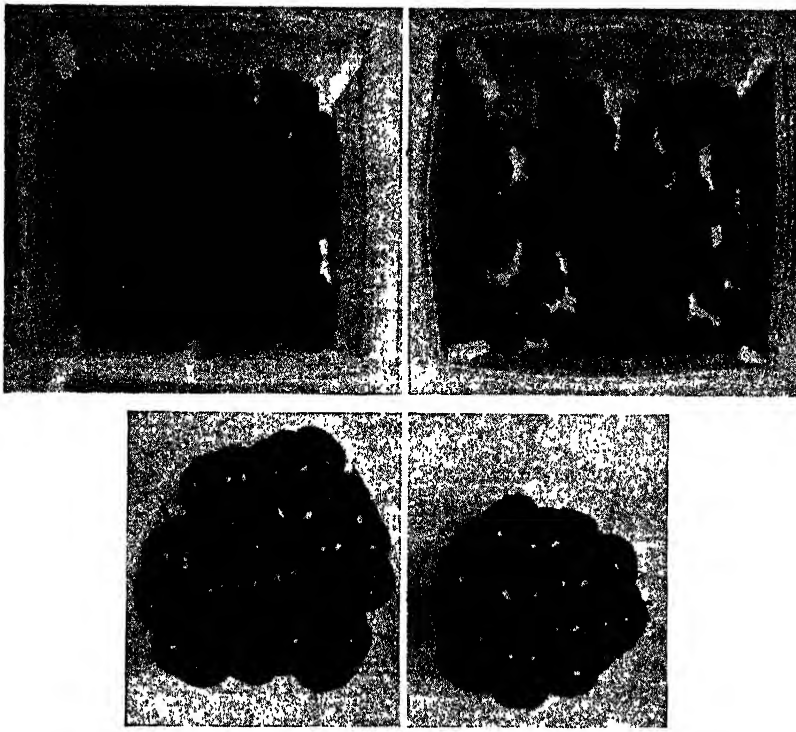

FIG. 1. Showing relative increase in blackberry fruit size resulting from application to the flowers of 40 ppm of an aqueous hormone mixture (40 per cent 4-chlorophenoxyacetic acid plus 60 per cent B-naphthoxyacetic acid) — Upper left, 100 berries from treated canes. — Upper right, 100 berries from control canes. — Lower left, treated berry, enlarged. — Lower right, untreated berry, enlarged.

that some chemicals or combinations of chemicals were more effective than others. Comparing treatments 1 and 2 with 3 and 4 for the earlier application, the effectiveness of B-naphthoxyacetic acid aqueous spray was greatly increased by the addition of 4-chlorophenoxyacetic acid. Indoleacetic acid, used at 250 ppm in aerosol, resulted in a greater increase in berry weight than did B-naphthoxyacetic acid at the same concentration. On June 6 the application of 3 different "hormone" aerosols (treatment 9) to the same plants resulted in a greater increase in mean berry weight than did any one of the particular growth-regulating chemicals applied singly. It may be that certain of the "hormones" have a synergistic action.

Effect of Time of Spray Application:—Although mean berry weight was increased significantly by treatment at both stages of flowering (see Table I), the earlier application in all but one case resulted in greater increases in fruit weight. At the 50-per-cent-stage of flowering, the mean fresh-berry weight for all nine treatments taken together showed a 63 per cent increase in favor of treatment

(212.6 ± S. E. 4.2 mg for the treated berries and 130.4 ± S. E. 3.1 for the control berries). Likewise the mean berry weight for all 8 late treatments (June 6 taken together was but 36 per cent greater than that for the controls (196.8 ± S. E. 8.0 mg for treated fruits and 144.7 ± 4.7 for the control berries).

To furnish information on the reliability of the fruit sampling method that was adopted, ten untreated plants were separated into halves and 100-fruit samples were removed from the two sides of the bushes at each sampling date. A comparison of the mean fresh-berry weights of these 100-fruit samples indicated that a difference in fruit weight of 8 per cent might be expected between the fruit on one half as compared with that on the opposite half of the same plants in 1 out of 20 comparisons. This difference attributable to method of sampling is small in comparison with differences due to treatments.

Summary

Four compounds, indoleacetic acid, indolebutyric acid, B-naphthoxyacetic acid, and 4-chlorophenoxyacetic acid, were tested by the liquefied-gas aerosol method, while B-naphthoxyacetic acid alone and in mixture with 4-chlorophenoxyacetic acid was tested in aqueous sprays on plants of a somewhat unfruitful blackberry seedling selection. One application was made when 50 per cent of the flowers had opened; another application to other plants was made when only 5 per cent of the flowers remained unopened. A significant increase over the controls was obtained in berry weight with all treatments. In all but one case the earlier application (May 26), when 50 per cent of the flowers were open, gave a significantly greater increase than similar applications made at a later date (June 6), when all but 5 per cent of the flowers had opened. An increase in berry weight of 99 per cent resulted from treatment with an aqueous spray application of 40 ppm concentration of a "hormone" mixture of 40 per cent 4-chlorophenoxyacetic acid and 60 per cent B-naphthoxyacetic acid. Treatments noted herein stimulated the development of the receptacle and of the pulp of the individual drupelets and increased the number of drupelets and seeds per fruit; but many of the seeds were small and undeveloped, so that the ratio of seed weight to fresh-berry weight was actually less in treated fruit than in controls.

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The Effect of Micro-elements on the Red Raspberry in Coastal British Columbia

By G. Howell Harris, *University of British Columbia, Vancouver, B. C.*

Previous work (1) had indicated that certain responses of crops could be obtained by applications of boron, copper, manganese and zinc to the glaciated light sandy-loam upland soils of coastal British Columbia. These soils have a reaction of around pH 6, are low in organic matter and are usually well leached of nutrients by the winter rains.

Methods

To ascertain the effects of these micro-elements on the red raspberry a planting of the Cuthbert variety growing at the University, approximately one acre in size was selected. This planting was originally set out in 1938. The treatments began in 1941. The block was laid out in the form of a 5 x 5 Latin square, each of the five treatments, including the controls being replicated five times. All plots received a basic fertilizer treatment of 5–10–5. The plots other than the controls received borax, copper, manganese and zinc sulphates at the rates of 50, 30, 50, and 15 pounds per acre respectively.

On harvesting, the fruit from each plot was picked and analyzed separately and the results treated statistically according to the methods outlined by Paterson (3).

The treatments were applied April 15 in 1941 and 1943. Only the basic fertilizer 5–10–5 was applied to all plots in 1942.

The yields, soluble carbohydrates determined on the juice with a refractometer, vitamin C determined by the method of Morrell (2) and dry weights determined by drying 50-gram samples in a ventilated oven for 12 hours at 70 degrees C and then in vacuo to constant weight are shown in the results below.

Results

The Effect of the Micro-elements on Yield:—Yields were very uniform throughout the three years of the experiment. With the exception of manganese applications in 1941 and 1943 no significant increases in yield were obtained by the treatments. An average of the 3 year's results shows that manganese only gave a significant increase in yield.

TABLE I—The Effect of Boron, Copper, Manganese and Zinc on Yield of Raspberries

Treatment	1941 (Pounds)	1942 (Pounds)	1943 (Pounds)	Average (3 Yrs) (Pounds)
Check	1,250	1,308	1,153	1,171
Boron	1,195	1,321	1,180	1,231
Copper	1,093	1,274	1,014	1,127
Manganese	1,415*	1,350	1,297*	1,354**
Zinc	1,202	1,261	1,133	1,198

*Significant at 5 per cent level.
**Significant at 1 per cent level.

The Effect of the Micro-elements on Carbohydrate Content:—The carbohydrate content was increased by applications of manganese and zinc. Applications of boron increased carbohydrates but not enough to be significant at the 5 per cent level. The higher values in 1943 are a seasonal effect.

TABLE II—THE EFFECT OF BORON, COPPER, MANGANESE AND ZINC ON TOTAL CARBOHYDRATE CONTENT OF RASPBERRIES. (PER CENT FRESH WEIGHT)

Treatment	1941 (Per Cent)	1942 (Per Cent)	1943 (Per Cent)	Average (3 Yrs) (Per Cent)
Check	10.23	11.14	14.10	11.82
Boron	11.30	11.32	14.30	12.31
Copper	11.03	11.18	14.20	12.21
Manganese	12.24**	11.80*	15.04*	13.02*
Zinc	11.71*	11.30	14.50	12.50*

*Significant at 5 per cent level.
**Significant at 1 per cent level.

The Effect of the Micro-elements on Vitamin C:—Applications of boron and manganese increased the vitamin C content of raspberries all three years of the experiment as shown in Table III below.

TABLE III—THE EFFECT OF BORON, COPPER, MANGANESE AND ZINC ON VITAMIN C CONTENT OF RASPBERRIES. (MG PER 100 GM FRESH WEIGHT)

Treatment	1941 (Mg per 100 Gm)	1942 (Mg per 100 Gm)	1943 (Mg per 100 Gm)	Average (3 Yrs) (Mg per 100 Gm)
Check	16.25	20.43	32 40	23 02
Boron	18.34*	22.00*	34.24*	24.85*
Copper	15.95	20.80	21.06*	19.25
Manganese	18.14*	22 03*	41.00*	27 05**
Zinc	16 16	21.02	27 60	21.59

*Significant at 5 per cent level.
**Significant at 1 per cent level.

The Effect of the Micro-elements on Dry Weight:—Dry weight of the raspberries was increased significantly in 1942 by boron and by manganese and zinc in 1941 and 1943. However, when the three years results are totalled the results from the applications of boron as well as manganese and zinc become significant and the dry weight is increased by all three elements.

TABLE IV—THE EFFECT OF BORON, COPPER, MANGANESE AND ZINC ON DRY WEIGHT OF RASPBERRIES. (PER CENT)

Treatment	1941 (Per Cent)	1942 (Per Cent)	1943 (Per Cent)	Average (3 Yrs) (Per Cent)
Check	16.16	19.31	19.16	18.21
Boron	16.22	22.03**	19.40	19.21*
Copper	16.10	19.33	19.18	18.20
Manganese	16.95*	19.82	20.22*	18.99*
Zinc	16.91*	19.85	20.14*	18.97*

*Significant at 5 per cent level.
**Significant at 1 per cent level.

Conclusions

Boron applications significantly increased the vitamin C content and dry-weight of raspberries. There was a consistent increase in yield and carbohydrate content due to boron applications for each of the three years of the experiment although this increase was short of being significant at the 5 per cent level.

Copper had no effect when applied to the soil on either yield, carbohydrate content, vitamin C content or dry weight of raspberries.

Manganese applications increased yield, carbohydrate content, vitamin C and dry-weight.

Zinc applications increased the carbohydrate content and dry-weight of raspberries but not the yield or vitamin C content. These results are summarized in Table V below.

TABLE V—The Effect of Boron, Copper, Manganese and Zinc on Raspberries. (Summary — Three Years)

Treatment	Yield	Total Carbohydrate	Vitamin C	Dry Weight
Boron	0*	0*	+	+
Copper	0	0	0	0
Manganese	+	+	+	+
Zinc	0	+	0	+

+ = Significant increase
0 = No significant increase.
0* = Increase but not quite significant at 5 per cent level.

While, at present, visible symptoms of the micro-elements deficiencies are not apparent in the field the fact that the above responses of the fruit to their application can be obtained indicates that these deficiencies are real although not apparent.

It is concluded that in the area under investigation with continued cultivation leaching effects are such that boron, manganese and zinc deficiencies are likely to become pronounced enough to warrant their use in fertilizer programs.

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Frost Resistance Tests with Cold Liquids

By Jack A. Eades and B. L. Wade, *U. S. Department of Agriculture, Charleston, S. C.*

The most obvious defects in the conventional freezing box technique as used at the Vegetable Breeding Laboratory have been the freezing patterns that develop on plants in the tray and the inability to duplicate actual temperatures from one series to another. These defects led us to explore the possibility of using cold non-toxic liquids adjusted to desired temperature below 0 degrees C for direct immersions of test plants. Only preliminary experiments were completed before the senior author's induction into the Army; hence, this report includes equipment and procedure, with peas *(Pisum sativum)* as the test plant.

A thirteen-inch-square flat with adjustable soil-retaining and row-partitioning grills was used to permit inverting the planted flats without spilling the contents during immersion. Standard 13 x 26-inch greenhouse flats were halved to form the smaller more easily handled flats. Five-barred grills made of 1 x ½-inch material were held in place by 4-inch toggle bolts emerging through the centers of the grills and permanently fastened into the center of the bottom of the flat. The toggle nut was turned to adjust grill level.

A stout immersing-vat, 4 feet square and 1 foot deep, was constructed of plywood and lined with sheet metal.

Prior to being immersed in the vat the planted flats were inverted and placed between the rails of a wooden rack or immersing platform. This rack, with a maximum of nine flats containing approximately two thousand plants, can be lowered and raised as a unit to insure uniform submerging time for all plants. With the legs resting on the level bottom of the freezing vat a uniform depth of submergence for all plants is assured.

The pea plants are hardened a few days preceding freezing, in a cold room at 40 degrees F. During a part of each day these plants are illuminated artificially to prevent sugar depletion.

The cold liquid consists of a non-toxic anti-freeze agent, such as triethylene-glycol, in solution with water to adjust the freezing point of the medium. The liquid is cooled to the freezing point of the plant by introducing a quantity of the same solution frozen by exposure to a sufficiently low temperature in a food processing quick-freeze box. The amount of frozen solution required for a desired temperature is inversely proportional to its coldness and proportional to the temperature of the liquid. Due to the heat of fusion of the frozen mass in the liquid and the slow rate of heat exchange of the liquid, a definite and constant temperature is maintained for a period more than adequate for the freezing test. The melting point is determined by the dilution of the triethylene-glycol with the water. This dilution is adjusted to obtain the temperature desired, and can be determined by the following formula which is based on the principle that one gram molecule of a

non-electrolyte in one liter of aqueous solution lowers the freezing point 1.86 degrees C.

$$\frac{\text{Desired degrees C temperature reduction}}{1.86} \times \frac{\text{Mol. equivalent of non-electrolyte in ml}}{\text{sp. gr. of non-electrolyte}} = \text{Number of ml of non-electrolyte needed per liter of solution to obtain desired freezing point reduction.}$$

A small rotary pump was used to circulate the solution in the vat until temperature equilibrium was reached. A liquid temperature of 26 degrees F and an immersion of 10 minutes produces considerable killing of well-hardened pea plants.

We will not attempt to discuss the many causes of the variation that occurs in all frost resistance tests, but wish to point out that certain advantages exist because of the intimate contact between plant and freezing medium and the rapid heat exchange that takes place when plants are submerged in cold liquids. Our preliminary results indicate definite possibilities in selecting more cold-tolerant plants through the use of this method.

Phosphorus Availability and the Mineral Aggregate Used in Nutrient Solution Culture[1]

By ELWOOD W. KALIN, *Purdue University, Lafayette, Ind.*

WITHROW, Biebel and Eastwood (7, 8) and Laurie and Kiplinger (4) have found that it is difficult to maintain a high level of phosphorus and a pH of 7 or below in the nutrient solution when certain types of mineral aggregates are used for supporting the roots of plants. Furthermore, the phosphorus disappears more rapidly than it is reasonable to assume that the plants are absorbing it. The investigations described in this paper were conducted in an attempt to determine to what extent phosphorus is retained by the aggregate particles; and if the retained phosphorus was available to the plants in sufficient quantities to supply the needs of the plants for an extended period of time with a minimum amount of phosphorus in the nutrient solution.

METHODS AND RESULTS

Experimental investigations were carried on in the greenhouse and laboratory[2]. The greenhouse investigations were started in May with four individual nutrient solution boxes, using the sub-irrigation method of Withrow and Biebel (8). The boxes were constructed of Cypress wood and waterproofed with asphalt paint. Each box was approximately 4 feet long, 1½ feet wide and 6 inches deep of the V-bottom type. Each box was supplied 5 gallons of nutrient solution from a 5-gallon glass bottle. A series of three experiments are included in the investigations.

SERIES I

Three boxes were filled with calcareous gravel which contained 37 per cent calcium carbonate. A fourth box was filled with "Muscatine" gravel (from Muscatine, Iowa) which was composed mostly of dark granitic minerals and contained 7.7 per cent calcium carbonate. However, the "Muscatine" gravel was obtained from a bench that had been used for growing crops in nutrient solution for about 4 years, and it was found to have a considerable amount of phosphorus retained on the surface of the particles.

Two boxes of calcereous gravel and the "Muscatine" gravel were pretreated with a 10 millimole solution of monobasic $Ca(H_2PO_4)_2/L$ by flushing the boxes 5 times daily. The remaining box of calcereous gravel was flushed with tap water. After 3 days the phosphate solutions were renewed and the treatment continued 4 more days. A summary is found in Table I.

For growing the plants, boxes 1, 2 and 3 were then supplied with Purdue 2D nutrient solution minus the $Ca(H_2PO_4)_2$ and box 4, the check plot, was given the complete 2D solution.

[1]A portion of a thesis submitted to the Faculty of Purdue University, August 1942, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

[2]The laboratory investigations will be published separately.

TABLE I—Series I. Treatment of Mineral Aggregates

Box No.	Type of Aggregate	Pre-treatment	Presence or Absence of $Ca(H_2PO_4)_2$ in the Nutrient Solution
1	Used "Muscatine" gravel	2–10 mm/L $Ca(H_2PO_4)_2$	—
2	Calcareous gravel	2–10 mm/L $Ca(H_2PO_4)_2$	—
3	Calcareous gravel	Tap water	—
4	Calcareous gravel	2–10 mm/L $Ca(H_2PO_4)_2$	+

Withrow, *et al.* (8) recommend that the Purdue 2D solution be made up of commercial fertilizer salts, and it is assumed that these salts supply the minor elements. However, in order to be certain the plants were receiving enough minor elements supplement containing Fe, Mn, Cu, and Zn in the form of sulphates and boric acid was added to the nutrient solution every twenty days (8).

TABLE II—Purdue 2D Nutrient Solution Formula

Salt	mM Concentration	Elements (Ppm)
$MgSO_4$	0.5	12 Mg
KNO_3	10.0	390 K, 140 N
$(NH_4)_2SO_4$	1.0	36 NH_4 (28N)
$CaSO_4$	4.0	160 Ca
$Ca(H_2PO_4)_2$	0.5	31 P, 20 Ca

The solution in each bottle was renewed every 10 days in order that the plants would be certain to receive all the other necessary elements of nitrogen, potassium, calcium, etc. The used solutions were tested for phosphorus and pH before they were discarded. The summary of these tests are found in Table III.

TABLE III—Series I. Analysis of Nutrient Solutions after Use for 10 Days

Date	Box Number							
	1		2		3		4	
	P	pH	P	pH	P	pH	P	pH
May 31	13 ppm	6.8	9 ppm	7.0	0 ppm	7.4	8 ppm	7.2
June 10	13 ppm	7.2	2 ppm	7.2	0 ppm	7.4	3 ppm	7.4
June 20	4	8.6	0	8.6	1	8.3	1	8.5
July 1	2	8.6	0	8.2	1	8.6	1	8.4
July 10	1	8.0	trace	8.0	trace	8.1	1	8.0
July 20.	1–	8.6	trace	8.6	trace	8.5	trace	8.5
July 30	1–	7.0	trace	7.7	trace	7.7	trace	8.0
Aug 10...	trace	8.0	0	8.1	0	8.2	1	8.8
Aug 19	trace	8.1	0	8.4	0	8.2	trace	8.5
Aug 29. .	trace	8.5	0	8.4	0	8.3	trace +	8.7
Sept 9. .	trace	8.3	0	8.1	0	8.2	trace	8.6
Sept 20	0	8.5	0	8.5	0	8.3	trace	8.5
Sept 30	0	7.6	0	8.0	0	7.8	trace	7.6

The boxes were planted with young tomato seedlings of the variety Indiana Baltimore at the rate of 48 seedlings per box. The seed had been sown in a mixture of one-half peat and one-half sand. Just 6 days after transplanting, the plants in untreated calcareous gravel and receiving minus P solution began to show phosphorus deficiency

symptoms and in 21 days the plants were almost dead. In order to save the plants, a 1 millimole per liter of $Ca(H_2PO_4)_2$ was added to the base nutrient solution for a 10-day period, hence the appearance of phosphorus in the discarded solutions for a short time.

Fifteen days after transplanting, half of the plants in each box were harvested and measurements of stem diameter, height, fresh weight and dry weight were obtained. Thirty days after transplanting all remaining plants, except 4 in each box, were harvested and measured. The results for the 15-day and 30-day plants were relatively the same and data for the latter are presented in Table IV.

TABLE IV—SERIES I. RELATIVE GROWTH OF 30 DAY OLD TOMATO PLANTS (Transplanted May 21. Harvested June 19.)

Box Number	Number Plants	Av Stem Diameter	Average Height	Average Fresh Weight		Average Dry Weight	
				Tops	Roots	Tops	Roots
		(Cm)	(Cm)	(Gms)	(Gms)	(Gms)	(Gms)
1	21	1.0	42.48	53.2	6.1	3.9	0.64
2	20	0.9	38.45	48.8	5.9	4.07	0.56
3	20	0.3	7.6	1.9	0.49	0 18	0.05
4	20	1.2	35.85	48.6	7.1	5.04	0.74

The data indicate that the pretreated gravel retained sufficient phosphorus to supply the needs of the young plants.

The 4 remaining plants in each box were allowed to mature and produce a crop. As the fruits matured they were picked and individually weighed and recorded. The results are found in Table V.

TABLE V—SERIES I. TOMATO FRUIT PRODUCTION DATA

Box Number	Number of Fruits	Total Weight of Fruit	Average Weight Per Fruit	Date of First Flower
		(Gms)	(Gms)	
1	71	8,247	116.1	6/24
2	64	6,677	104.3	6/25
3	18	1,897	105.4	7/14
4	76	8,157	107.3	6/26

The experiment was terminated before all fruits had ripened. The plants in "Muscatine" gravel and minus P solution had 4 and the check plot had 11 green fruits which are not included in the data of Table III. The data indicate that pretreated or previously used gravel is able to supply almost sufficient phosphorus to support the growth of one tomato crop.

SERIES II

A second experiment was started in the fall. The same boxes and irrigation system were used; however, a few changes were made as follows: fine Haydite was substituted for untreated calcareous gravel; because of the relatively low solubility of calcium phosphate salt, potassium phosphate was substituted at the same concentration in parts per million.

The phosphorus pretreatment was carried on for 20 days, using two changes of solution (10 mm/L of KH_2PO_4). Before discarding the

solutions they were tested to see how much phosphorus was retained. Of the 620 ppm of P (1900 ppm of PO_4) contained in each solution used for pretreating each box, the calcareous gravel boxes retained 505 ppm, Haydite 360 ppm and "Muscatine" gravel 350 ppm. A summary is found in Table VI.

TABLE VI—SERIES II. TREATMENT OF MINERAL AGGREGATES

Box No.	Type of Aggregate	Pre-treatment	Presence or Absence of KH_2PO_4 in the Nutrient Solution
1	Haydite	2-10 mm/L KH_2PO_4	—
2	Calcareous gravel	2-10 mm/L KH_2PO_4	—
3	Calcareous gravel	2-10 mm/L KH_2PO_4	+
4	Used "Muscatine" gravel	2-10 mm/L KH_2PO_4	—

The boxes were then planted with 48 tomato seedlings per box. Fresh solutions were made every 10 days for 140 days. The solutions were tested for P concentration and pH before being discarded. The calcareous gravel boxes showed 14 ppm, "Muscatine" gravel showed 35 ppm and Haydite showed 35 ppm for the first 10 day period. After 40 days, the concentration of phosphate in solution was 3 ppm for Haydite, 1 ppm for calcareous gravel receiving minus phosphate solution, 4 ppm for calcareous gravel with complete solution and 5 ppm for "Muscatine" gravel. After 100 days, pretreated calcareous gravel receiving minus P solution showed no P in solution. The remaining boxes showed 1 ppm to a trace when the experiment was ended at 140 days. The pH was slightly above 8 for all boxes, and were always within 0.5 of a pH of one another, so it is assumed the plants were growing under similar conditions of pH.

After 43 days from transplanting all but four plants from each box were harvested and the data are found in Table VII.

TABLE VII—SERIES II. RELATIVE GROWTH OF 43 DAY OLD TOMATO PLANTS
(Transplanted November 5. Harvested December 18)

Box Number	Number Plants	Average Height (Cm)	Average Fresh Weight		Average Dry Weight	
			Tops (Gms)	Roots (Gms)	Tops (Gms)	Roots (Gms)
1	42	23.65	8.33	0.80	0.49	0.08
2	41	37.30	16.34	1.38	1.1	0.13
3	44	40.50	17.04	1.04	1.1	0.11
4	44	45.67	21.35	1.35	1.3	0.12

"Muscatine" gravel again produced the best plants. It is interesting to note the similarity of the plants in the pretreated calcareous gravel boxes. The plants receiving no additional P in the nutrient solution grew as well as those receiving complete solution. This indicates enough P was retained and available for the early growth of a large number of plants. The 4 remaining plants in each box were left to mature and produce fruit. Just as the plants reached full production the wire supporting the plants gave way on April 11. This accident made accurate production records impossible because many of the green fruits were knocked off and scattered among the boxes. How-

ever, the plants were allowed to grow in preparation for Series III. Observation of the plants previous to the accident indicated that the set of fruit in all the gravel boxes were equal. The Haydite box had quite a few fruits set, but they were later than those in the other boxes.

Series III

In Series III the object was to determine whether the plants that had grown in each box had depleted the aggregate of its available phosphorus. The aggregates received no additional treatment and the boxes were kept on the same solutions as in Series II. Tomato seedlings were transplanted to the boxes on May 12 at the usual rate of 48 plants per box.

The solutions continued to be renewed every 10 days and tested before discarding. The Haydite and calcareous gravel minus P solution boxes showed no P in solution and the "Muscatine" gravel box was reaching the point that indicated it had less than 1 ppm. The check box continued to test 1 ppm of P as usual.

The plants were allowed to grow for 30 days before harvesting and the results are recorded in Table VIII.

TABLE VIII—Series III. Relative Growth of 30 Day Old Tomato Plants
(Transplanted May 12. Harvested June 11)

Box Number	Number Plants	Average Height (Cm)	Average Fresh Weight		Average Dry Weight	
			Tops (Gms)	Roots (Gms)	Tops (Gms)	Roots (Gms)
1	47	15.1	5.8	2 4	0.59	0.27
2	46	29 9	14.5	2.0	1.1	0.27
3	46	46.0	28.8	2.1	1.9	0 26
4	48	44.7	23.6	2.2	1.7	0.22

The results shown in Table V indicate that the mineral aggregates in the boxes receiving no additional P in the nutrient solution had been almost completely depleted of phosphorus. The most interesting comparison is between the two calcareous gravel boxes. In Series II, when the gravel had just been pretreated, the young plants made the same amount of growth regardless of the amount of P in the nutrient solution; however, in Series III the plants receiving additional P in the nutrient solution made almost twice as much growth in height and in weight as those receiving no additional P. This indicates that the phosphorus pretreatment of the gravel enables it to provide sufficient P for only one crop of tomatoes. Furthermore, the young plants in Series III, receiving no additional P, showed definite phosphorus deficiency symptoms as evidenced by their darker green color, purple vernation on the underside of the leaf and stunted growth. The "Muscatine" gravel appeared to be reaching the point where its retained supply of P was getting low. The poor showing of the plants in Haydite indicates that there was very little reserve phosphorus in it; however, because of the extreme difference in physical properties of gravel and Haydite it would not be safe to draw any definite conclusion until further research has been done.

Cullinan and Batjer (2), Tidmore (6), Lyness (5) and Kalin (3) report that although the per cent of phosphorus found in the plants is not directly proportional it is closely correlated with the concentration of phosphorus in the nutrient solution or the amount available to the plants. An analysis was made of the dried plant material of Series III, using the Bell-Doisy-Briggs method (1) for determining phosphorus content of organic material. The results obtained, as presented in Table VI, indicate that the amount of plant growth is correlated with the per cent of phosphorus found in the plant.

TABLE IX—SERIES III. PHOSPHORUS ANALYSIS OF 30 DAY OLD TOMATO PLANTS
(Harvested June 12)

Box Number	Aggregate	Nutrient Solution	Phosphorus* (Per Cent)
1	Haydite	$-PO_4$	0.177
2	Calcareous Gravel	$-PO_4$	0.243
3	Calcareous Gravel	Complete	0.355
4	Muscatine Gravel	$-PO_4$	0.266

*On Dry-weight basis.

CONCLUSION

From the data presented it is reasonable to conclude that a new calcareous gravel containing 37 per cent limestone will remove nearly all of the phosphate of a high phosphate solution within 3 weeks or less. "Muscatine" gravel, containing about 8 per cent limestone, previously used for nutrient solution work will remove large quantities of phoshorus from a high phosphate solution. This removed phosphate will then support the phosphate requirements of a tomato crop for a considerable period of time, showing that the phosphate retained in the pre-treatment is still largely available for use by tomato plants although the concentration in the nutrient solution may appear inadequate.

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Modification of the Phenoldisulfonic Acid Method for Potassium to Increase Rapidity and Accuracy[1]

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In estimating potassium from the amount of nitrogen in the potassium cobaltinitrite precipitate, as recently reported (1), trouble sometimes is had in getting rid of the excess of chlorate used to oxidize the nitrite to nitrate. This is avoided by using monochloracetic acid as proposed in a recent paper (2). Also, the heat needed to decompose the potassium cobaltinitrite with alkali can be supplied from chemical reaction, instead of heating over a burner, which makes the method easier for use in the fields. The following procedure has proved satisfactory.

PROCEDURE

Precipitate the potassium as cobaltinitrite and wash the precipitate as usual, (1). Push the asbestos plug and cobaltinitrite precipitate from the funnel into the 30 cc test tube. Flush the funnel with 2 cc of 40 per cent NaOH into the tube and add, fairly rapidly but with vigorous shaking, .5 cc of 50 per cent H_2SO_4. Shake and when the precipitate has all darkened, make to 25 cc with water (50 cc or more if K is high). Allow to stand until the precipitate settles, or it may be filtered off at once if so desired. The solution will keep several days, and nitrogen determination can be made as time permits.

Determining the Nitrate Nitrogen:—Place about 1 gm of monochloracetic acid in a dry test tube. This may be measured. Put .5 cc of the unknown solution on the crystals and add 1.2 cc of 40 per cent NaOH solution. Known K solutions and blanks should be run in the same way along with the unknown. Add 0.5 cc of 40 per cent $NaClO_3$ and shake. Now add 2.5 cc of fuming sulfuric acid just rapidly enough to avoid excessive boiling. If a yellow color does not persist here, not enough chlorate was used. Shake and blow out fumes with a bent glass tube. Most of the yellow color should disappear. Cool and add 3 cc of phenoldisulfonic acid. Shake well and add 20 cc of water. Pour into a 50 cc graduated flask, rinse the tube into the flask and neutralize with 40 per cent NaOH, adding a moderate excess. The end point is told by the formation of the yellow color.

TABLE I—RESULTS ON KNOWN K SOLUTION

K Added (Mg)	K Found (Mg)
0.5	0.5
0.75	0 75
1.0 Used as standard	1.0
1.5	1.5

[1]The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

Make to 50 cc (or more if necessary). Compare with a standard made in the same way from a solution containing 1.0 mg of K per cc. Subtract the blank from unknown and standard readings and calculate the K in the sample. Numerous duplicates were made and all checked out almost identically. The averages showed complete recovery.

Table II shows that the effect of potash fertilizer was detected though differences were rather small. The soil was quite high in K to start with and the approximate turbidity tests showed no differences, but when the phenoldisulfonic acid method was used, some differences

TABLE II—RESULTS ON EXTRACTS OF POTATOES

Plot	KCl Per Acre (Lbs	K of Lower Petiole (Ppm)
1	0	7,000
2	150	5,200
3	300	8,700
12	0	6,000
15	150	7,100

were apparent. Why the 150 pound addition (Plot 2) was lower than the check cannot be explained, but the extract was re-run numerous times and gave the same low figure, so that the low figure was not error in the method. In fact, duplicates on all extracts checked almost perfectly in so far as could be told on the electric colorimeter which read small differences very accurately if the yellow color was not too great.

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Some Factors Influencing the Reliability of Plant Tissue Testing[1]

By JAMES F. HARRINGTON, *Cornell University, Ithaca, N. Y.*

ALTHOUGH considerable work has been done on the accuracy of the methods of analysis in plant tissue testing, less has been done on the role of environmental factors or the role of the plant itself on the concentration of a given ion in plant tissues. The data in this paper are concerned with the effect of fertilizers, age of plant, tissue of plant, and soil differences on the soluble nitrate, phosphorus and potassium concentration in the plant tissues. The chemical methods used were those described by Peech and English (1).

THE EFFECT OF SOIL VARIATION

Beans were grown on two soils during the summer of 1943. One soil was a Dunkirk Fine Sandy Loam of about pH 6.2. It had received heavy applications of fertilizer in recent years but due to heavy spring rains it had been leached and was low in nitrogen. The other soil was a Dunkirk Silty Clay Loam about three miles distant and nearly the same elevation as the sandy loam. It had a pH of approximately 5.2 and had never been fertilized. It was severely deficient in phosphorus and low in nitrogen. The experimental area on each soil was fertilized, in a factorial design for nitrogen, phosphorus and potassium. Samples were taken weekly from emergence to harvest, a period of 6 weeks.

TABLE I—THE EFFECT OF SOIL TYPE ON ION CONCENTRATION IN THE TISSUE AND ON THE YIELD OF SNAP BEANS

Soil	NO_3-N	PO_4-P	K	Yield
	Ppm	Ppm	Ppm	Pounds per 192 Square Feet
Dunkirk Fine Sandy Loam	417	404	5,890	17.3
Dunkirk Silty Clay Loam	216	364	4,180	9 7
L.D. 1 per cent	23	15	200	0 95

The data in Table I indicate that bean plants grown in a soil of low fertility contain a lower concentration of soluble nitrate, phosphate and potassium ions than do bean plants grown in a more fertile soil. Plants from the silty clay loam soil had a concentration of soluble nitrates one-half as much, seven-eights as much soluble phosphates and three-fourths as much potassium as did the plants from the fine sandy loam soil. The concentration of all three ions was significantly less in the plants grown on the silty clay loam soil. The yield was also significantly less on the silty clay loam soil.

Table II amplifies the role that soil differences play in tissue testing. The plants from the high nitrogen plots on the fine sandy loam soil had a nitrate-nitrogen concentration of 530 ppm and yielded 18.2 pounds of beans per plot while those on the plots receiving no

[1]Paper No. 272, Department of Vegetable Crops, Cornell University.

TABLE II—THE EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZERS ON ION CONCENTRATION AND YIELD OF SNAP BEANS GROWN ON TWO DIFFERENT SOIL TYPES

Fertilizer	NO_3-N (Ppm)	Yield (Pounds)	Fertilizer	PO_4-P (Ppm)	Yield (Pounds)
		Dunkirk Fine Sandy Loam			
N_2	530	18.2	P_1	407	16.6
N_0	286	15.4	P_0	402	17.9
		Dunkirk Silty Clay Loam			
N_2	284	9.8	P_1	392	10.9
N_0	122	9.3	P_0	338	8.5
L.D. 1 per cent	39	1.6	—	21	1.4

nitrogen in 1943 had a nitrate-nitrogen concentration of 286 ppm and the yield from these plants was 15.4 pounds. Both the nitrate-nitrogen concentration and yield increased significantly when nitrogen was applied to the soil. It appears that nitrogen was limiting and in this soil 286 ppm of nitrogen was inadequate for maximum yield of beans.

Comparing the fine sandy loam and silty clay loam soils, the difference between 286 and 274 ppm of nitrate-nitrogen in the no-nitrogen fine sandy loam plots and the high nitrogen silty clay loam plots is not significant yet the yield dropped from 15.4 pounds to 9.8 pounds, a very significant decrease. It appears that some factor or factors other than nitrogen in the soil were limiting in the silty clay loam soil.

If the high and no-nitrogen plots on the silty clay loam soil are compared the data in Table II indicate that the nitrate-nitrogen concentration decreased from 274 to 122 ppm a significant decrease, while the yields are respectively 9.8 and 9.3 pounds per plot, the difference being insignificant. On the silty clay loam soil, a poor soil, more than 122 ppm of nitrate-nitrogen did not increase the yield of snap beans but on the fine sandy loam soil which is highly productive 286 ppm of nitrate-nitrogen was insufficient for maximum yield. One reason for the low yield on the silty clay loam soil probably was inadequate phosphorus as is indicated in Table II; other reasons might have been the low pH and low soil pore space.

EFFECT OF AGE OF PLANT

Spinach seed was planted in quartz sand in 4-inch clay pots September 23, 1943 in the greenhouse. On October 15, the plants were thinned to one to a pot. The nutrients were supplied using Hoagland's solution 1 with modifications for the low nutrient levels. The L (low) levels were one-half the Hoagland concentration of nitrogen, one-fourth that of phosphorus and one-fourth that of potassium. On November 9, the nutrient in question in the L-o solutions was completely removed and was not added subsequently.

Table III shows the variations in concentration of nitrate-nitrogen, phosphate-phosphorus, and potassium in the spinach petioles as the plants aged.

TABLE III—THE CHANGE IN NITRATE-NITROGEN, PHOSPHATE-PHOSPHORUS AND POTASSIUM CONCENTRATION IN THE SPINACH PETIOLES AS INFLUENCED BY AGE OF PLANT AND NUTRIENTS APPLIED

Nutrient Solution	Date									Final Yield (Gms)
	Oct 9	Oct 16	Oct 24	Oct 30	Nov 8	Nov 17	Nov 24	Dec 1	Dec 8	
					NO_3-N (Ppm)					
N, LP, LK	700	1,000	863	944	691	619	740	950	1,200	14.90
N, P, K. . . .	900	1,000	875	1,025	567	570	488	625	975	20.30
L-oN, P, K .	400	463	506	494	321	143	21	14	12	4.76
L.D. 1 per cent . .	357	252	252	252	206	237	237	237	237	2.13
					Po_4-P (Ppm)					
LN, P, LK . .	450	506	257	481	629	444	278	472	506	11.87
N, P, K	500	425	250	400	583	313	138	313	225	20.30
N, L-oP, K	250	219	125	269	242	138	67	110	118	7.80
L.D. 1 per cent .	242	171	171	171	140	112	112	112	112	2 13
					K (Ppm)					
LN, LP, K	6,000	7,570	6,640	8,170	7,650	9,150	6,190	9,450	10,350	12.08
N, P, K	6,000	7,200	6,300	6,600	7,800	8,550	4,350	8,700	7,200	20.30
N, P, L-o K .	5,700	4,650	5,550	5,550	6,400	4,610	3,450	3,110	3,150	7.58
L.D. 1 per cent.	2,330	1,650	1,650	1,650	1,350	1,340	1,340	1,340	1,340	2.13

Where the N, P, K or complete solution was applied the nitrate-nitrogen concentration was approximately the same at the last sampling date as it was at the first sampling date, 975 ppm vs 900 ppm. Where nutrients other than nitrogen were low there was a significantly higher concentration as compared with the checks from November 24 to December 8, although the rise in nitrate-nitrogen concentration was not pronounced until December 8, when the concentration was 1200 ppm. Where the nitrogen supplied was low and the other elements were adequate the nitrate concentration was significantly lower even at the earliest sampling date as compared to the concentration in the plants receiving a complete solution, 400 ppm vs 900 ppm. After November 9, when no further nitrogen was added, there was an abrupt drop from 321 ppm to 143 ppm on November 17 and to 21 ppm on November 24.

The same trends are evident in the phosphate-phosphorus and in the potassium concentrations. Where other elements are low there is a steady rise in the concentration of the ion being measured as compared to that in the plants receiving a complete solution as the plants mature and where the element in question is low the ion concentration decreases with the age of the plant.

The phosphate-phosphorus concentration increased from 450 ppm to 506 ppm where other elements were low and decreased from 250 to 118 ppm where phosphorus supplied was low.

Likewise the potassium concentration increased from 6000 ppm to 10350 ppm where other elements were low and decreased from 5700 to 3150 ppm where potassium supplied was low.

In the plants receiving the complete solution the nitrate-nitrogen and potassium concentrations remained about constant while the phosphorus concentration decreased considerably as the plants matured. The phosphate-phosphorus concentration in the older plants receiving

the complete solution was frequently less than that in the younger plants which had only received a low supply of phosphorus.

With the beans grown in the field there was a significant decrease in nitrate-nitrogen concentration in both the growing tissue and the stem tissue as the plants aged while the phosphate-phosphorus concentration tended to increase and the potassium concentration showed no definite trend.

Effect of Tissue Tested

The data in Table IV indicate to some extent whether the blade or petiole tissue is more useful as a measure of changes in the nutrients available to the plant. With one non-significant exception the change in the concentration of a nutrient was in the same direction in both tissues as a result of a change in the nutrient supply. For example. the high nitrogen solutions increased the nitrate-nitrogen concentration to 862 ppm in the petiole tissue from that of 194 ppm where the plants had received only the nitrogen concentration. Likewise, the concentration in the blades was increased from 290 to 380 ppm. On the other hand, the high applied nitrogen decreased the phosphate-phosphorus concentration from 373 to 226 ppm in the petiole tissue and from 530 to 486 ppm in blade tissue.

TABLE IV—The Mean Concentration of Ions in the Fresh Blade and Petiole Tissue of Spinach and the Mean Yield as a Function of the Level of the Applied Nutrient

Nutrient Level	Ion Concentration (Ppm)						Yield (Gms)
	NO_3-N		PO_4-P		K		
	Petiole	Blade	Petiole	Blade	Petiole	Blade	
N	862*	380*	229	486	5,830	6,350	7.30*
-N	194	290	373	530	7,670*	7,180*	3.56
P	459	253	447*	674*	6,160	6,560	6.17*
-P	598*	327*	151	343	7,390*	6,980	4.69
K	507	301	262	477	8,750*	7,920*	6.43
-K	550	279	337*	540*	4,800	5,620	4.44
L.D. 1 per cent	70	39	48	48	460	560	0.59

In eight of the nine comparisons between the high and low level of the nutrient applied, the differences in concentration in the petiole were significant, while the differences were significant in only six of the nine in the blade tissue. The nitrate-nitrogen concentration in the plants receiving high or low potassium did not differ significantly in either tissue. The absolute magnitude of the difference was larger in the petiole tissue in all nine comparisons and the percentage difference was greater in the petiole tissue in six of the nine comparisons.

Not only were the differences usually greater in the petiole tissue but also the petiole tissue usually mirrored a change in the nutrient level applied more quickly than did the blade tissue. There was a significant decrease in nitrate-nitrogen concentration in the petiole

one week after nitrogen was removed from the applied solution while the decrease in nitrate-nitrogen concentration in the blade was not significant until 4 weeks after the change. Likewise there was a significant decrease in potassium concentration in the petiole three weeks after potassium was removed from the solution while the decrease in the concentration in the blade was never significant. Neither the petiole nor the blade showed a significant decrease in concentration of phosphate-phosphorus when phosphorus was removed from solution.

Effect of Fertilizers

Again referring to Table IV, it is seen that with one exception decreasing either nitrogen, or phosphorus, or potassium decreased the concentration of the respective ion in the plant tissue and increased the concentration of the other two ions. The exception was that decreasing potassium had no effect on the nitrate-nitrogen concentration in the spinach tissue.

Summary and Conclusions

It was found that although differences in the available nutrient supply could be measured by analysis of the extract of fresh plant tissue the results obtained were applicable to only one soil as the differences due to soil type masked the differences due to availability of a given element in the soil. Therefore, before this method can be used widely some method of evaluating the differences due to soil type must be evolved.

There was a drift in concentration of an element as the plant matured. It seemed that the most important cause of this drift was the nutrient balance. When an element was low the concentration of its ion decreased as the plant matured and when another or other elements were low the concentration of the ion increased as the plant matured. This drift might be used as a more reliable guide to fertilizer needs than the absolute amount of an ion present in the tissue at any given testing date.

The evidence strongly indicates that the conducting tissue such as the petiole of the spinach and the stem of bean is a more reliable guide than other tissues since the magnitude of differences is greater and the response to a change in available supply is quicker in the conducting tissue. It is clear that it is absolutely essential to sample the same morphological region or tissue when making comparisons, as the differences between tissues is usually greater than the differences between fertilizer treatments.

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Some Physiological Effects of Methyl Bromide Upon Horticultural Plants[1]

By G. H. BEAMES and N. W. BUTTERFIELD, *R. I. State College, Kingston, R. I.*

DURING the past few years there has been much experimentation on the use of methyl bromide as a fumigant for control of insects infesting grains, dormant nursery stock, bulbs, tubers and actively growing plants. Fumigation of dormant material with methyl bromide is reported to be successful from a commercial standpoint, but there are conflicting views as to the advisability of the treatment of actively growing plants.

This experiment was designed to determine some of the physiological effects of methyl bromide gas upon actively growing plants. The plan was to study the effect of methyl bromide upon transpiration and respiration rates, accumulation of break-down products in plants, and oxygen content of the soil.

EXPERIMENTAL METHODS

The plants were subjected to the vapors of methyl bromide in a specially constructed fumigation chamber. The capacity of the chamber was 50 cubic feet. It was insulated and had an air-tight lining of galvanized sheet metal. The temperature was thermostatically controlled by a sensitive mercury switch which was attached to three 150-watt heating units. The air in the chamber was kept in constant circulation during the fumigation period by means of an electric fan. By lowering a small trap into the circulating tunnel this same fan evacuated the gas from the chamber to the outside of the greenhouse.

Methyl bromide liquid was introduced by means of a special device capable of accurately measuring it in cubic centimeters. The liquid was then vaporized and allowed to pass into the chamber through a copper tube. Any liquid not previously volatilized dropped on a pan over the heating coil.

TABLE I—LOSS OF WATER BY TRANSPIRATION OF FUMIGATED AND NON-FUMIGATED PLANTS

Plant	Loss of Water (Gms)	
	Fumigated	Non-fumigated
Cineraria	106.7	107.0
Poinsettia	90.8	93.8
Tomato	65.0	65.7

The measurement of the oxygen in the soil was accomplished by means of a modified gas absorption device. One hundred and thirty grams of potting soil was placed in a 125-ml flask. After fumigation, the air in the flask was displaced into a closed system and bubbled

[1]Contribution No. 655 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

through alcohol into a burette. The oxygen was then absorbed by pyrogallic acid and the calculations were made in the usual manner.

The rate of transpiration was measured by successive weighings of plants which had been sealed in brass containers with paraffin. The respiration rate of plants was measured by a modification of the method designed by Heinicke and Hoffman (1). Ammonia and amino nitrogen in plant tissues were measured by methods described by Schlenker (2). A high relative humidity in the chamber was attained by spraying the leaves and the walls of the chamber with a fine mist before fumigation.

TABLE II—THE EFFECT OF METHYL BROMIDE UPON THE OXYGEN CONTENT OF THE SOIL

Treatment	Oxygen (Per Cent)
Non-fumigated soil	17.7
Fumigated soil (immediate analysis)	4.5
Fumigated soil (analysis after 1 week aeration)	15.7

The experiments reported in this paper were carried out under the following conditions: high relative humidity (90 per cent), moderate temperature (70 degrees F), 20 ml of liquid methyl bromide per 50 cubic feet or 1.521 pounds per thousand cubic feet, and an exposure of 2 hours. Preliminary studies indicated that these conditions seemed to be optimum for a wide range of plants and gave nearly 100 per cent control of red spider.

RESULTS

Fig. 1 shows typical examples of methyl bromide injury. Fumigation of tomato seedlings resulted in wilting and burning of the leaves. The extent of the injury is emphasized by the fact that even 2 weeks after treatment the fumigated plants were decidedly stunted.

Young potted spruce trees about 18 to 20 inches tall reacted to the

FIG. 1. Effect of methyl bromide fumigation on tomato seedlings. No treatment (left); treated, plants stunted (right).

TABLE III—Effect of Methyl Bromide Upon the Respiration of the Spruce

Time of Reading	Number of Hours Elapsed	Fumigated Plants Mg CO_2 per Branch for 15 Minutes			Controls Mg CO_2 per Branch for 15 Minutes		
		A	B	Ave	A	B	Ave
7 p.m.	3	0.57*	0.95	0.71	1.80	2.50	1.93
9 a.m	15	0.57	0.87	0.62	2.12	2.45	2.29
2 p m.	20	0.50	0.70	0.60	2.12	2.60	2.36
7 p.m.	25	0.57	0.40	0.49	2.05	1.41	1.73
9 a.m.	39	0.65	0.80	0.72	2.30	2.12	2.21
1 p.m.	43	1.27	0.90	1.09	1.80	2.50	2.15
9 a.m	57	1.95	1.01	1.48	1.35	2.12	1.74
5 p.m.	65	2.05	1 35	1.65	1.90	2.35	2.13

treatment in a different manner. These trees were dug from the nursery in late September and placed in 8-inch pots. They were kept in a cold frame until November. The plants were then brought into the greenhouse (45 degrees to 50 degrees F). In late December after new growth had started, the plants were fumigated. They showed no injury until the seventh week and then the leaves began to drop.

In order to better understand the nature of wilting caused by methyl bromide, the rate of transpiration of treated plants was measured and compared with that of the check plants. The data presented in Table I show that methyl bromide had no effect on the rate of transpiration of Cineraria, Poinsettia, and tomato.

TABLE IV—The Effects of Methyl Bromide Upon the Respiration of Small Tomato Seedlings

Time of Reading	Number of Hours Elapsed	Mg of CO_2 per Plant for 15 Minute Periods				
		Fumigated Plants				Controls
		A	B	C	Ave.	
5 p.m.	2	1.90	1.45	1.57	1.64	2.00
10 p.m.	6	1.20	1.60	0.70	1.17	2.15
11 a.m.	19	—	0.50	1.60	1.05	1.50
3 p.m.	23	1.70	—	1.52	1.61	2.00
7 p.m.	27	—	1.70	—	1.70	1.60
10 p.m.	44	1.61	—	2.15	1.88	0.80
7 p.m.	53	2,25	0.70	1.00	1.33	0.35
9 a.m.	66	—	0.50	1.05	0.78	0.00

Since there was no difference in the rate of water loss between treated and untreated plants, studies were made to check the possibility that methyl bromide might have interfered with water absorption by roots. The plants whose roots were sealed with paraffin did not wilt as a result of fumigation.

Samples of soil atmosphere were taken from sealed and non-sealed pots after fumigation, and analyzed for oxygen content. The results given in Table II show that the oxygen content of treated soil was decreased by 80 per cent immediately after fumigation. It is not surprising since methyl bromide is a heavy gas — nearly three times

FIG. 2. Effect of methyl bromide treatment on spruce trees. Photograph taken 10 weeks after treatment. No treatment (left); slight injury, loss of half the needles (center); severe injury, loss of all needles (right).

heavier than air and highly diffusive. After one week the soil atmosphere returned to a nearly normal condition.

In order to throw light on the nature of the burning shown by leaves of fumigated plants, the rate of respiration of excised spruce branches and tomato seedlings was determined. It was found that the fumigated branches respired at a rate of about 50 per cent of the check.

Chemical analysis of fumigated tomato leaves showed that ammonia nitrogen increased by 12.5 per cent at the end of 4 hours after treatment and 47 per cent at the end of 52 hours. At the end of 90 hours ammonia nitrogen in the treated leaves was only 26 per cent higher than in the leaves of check plants. After 162 hours there was little difference in ammonia nitrogen content between fumigated and nonfumigated plants. Amide nitrogen was also found in greater amounts in fumigated tomato leaves. This increase was noted both in glutamine and asparagine. The data are shown in Table V and VI.

TABLE V—EFFECT OF METHYL BROMIDE UPON THE AMMONIA NITROGEN CONTENT OF TOMATO LEAVES

Time Interval (Hours)	Control—Mg per Ml of Plant Juice	Fumigated—Mg per Ml of Plant Juice
4	0.0236	0.0264
28	—	0.0346
52	0.0229	0.0340
90	0.0228	0.0292
162	0.0229	0.0222

TABLE VI—EFFECT OF METHYL BROMIDE UPON AMIDE NITROGEN CONTENT OF TOMATO LEAVES 30 HOURS AFTER TREATMENT

Forms of Amide Nitrogen	Control—Mg per Ml of Plant Juice	Fumigated—Mg per Ml of Plant Juice
Asparagine	0.010	0.012
Glutamine	0.007	0.020
Total amide nitrogen	0.017	0.032

SUMMARY

The growth of young tomato seedlings was greatly checked when treated with methyl bromide. The injurious effect of methyl bromide on young spruce trees was not observed until the seventh to the tenth week.

Fumigation with methyl bromide had no effect on the transpiration rate of the plants used in this experiment. However, the normally potted plants when fumigated showed some degree of wilting, but sealing the roots prevented this. Methyl bromide, which is heavier than air, reduced the oxygen content of the soil approximately by 80 per cent. Wilting may be attributed to the reduction of oxygen in the soil which reduced the absorption of water by the roots.

The rate of respiration was found to be reduced about 50 per cent with excised spruce branches and some reduction is evident with young tomato seedlings. There was an increase in amide and ammonia nitrogen in the plant tissues immediately after treatment. The rate of respiration of young tomato seedlings was also reduced by the methyl bromide treatment, but the difference was not as pronounced as with the spruce branches.

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Plunging of Potted Plants in Relation to Moisture and Nutrient Supply

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From time to time in the work of the U. S. Plant Introduction Garden at Glenn Dale, Md., the old practice of plunging, i. e., sinking to their brim, in sand or peat, of pots containing plants of rather exacting requirements has proved decidedly advantageous, apparently through ensuring greater uniformity of soil moisture. The benefits obtained by plunging thus were so striking that the practice was extended to less exacting plants, where the gains were still pronounced. In addition to the better growth thus obtained, economy in labor expended in care was striking, and plunging is now rather generally used on the smaller plants. The advantages of this practice seemed pronounced enough to warrant some quantitative study of the results obtained and exploration of the ways by which the process operates. This paper presents a record of this study.

Previous experience had shown that in many cases watering of the plunging material provided ample moisture for the potted plants, thus sparing the plants the compacting of the soil that inevitably accompanies direct watering, particularly in winter when artificial heat is in constant use and humidity low. Jones (1) has shown that water evaporates rapidly from the walls of unglazed pots. The first step in this inquiry was directed toward an appraisal of the rate and magnitude of the movement of water through the walls of the pots, in either direction. To this end, 2-inch, 3-inch and 4-inch pots, containing soil but no plants, were used. The upper quarter-inch of each pot was dipped in melted paraffin and the pots were all immersed in water and then drained, to equalize the water content of the pot walls so far as possible. The soil placed in the pots was a fine sandy loam, not manured, to which was added one third, by weight, of sand; its water holding capacity was 31 per cent of its dry weight. The soils were moistened to three levels; low (7.1 per cent), medium (14.55 per cent), and high (20.8 per cent), before they were placed in the pots and the surface of the soil in each pot was covered with a layer of paraffin, in which a very small hole, intended to permit possible air replacement, was made. The pots were then plunged in a bed of peat, 10 inches deep and divided into three compartments, which were held at moisture contents averaging respectively 161, 354, and 425 per cent of its dry weight by periodic sampling and water additions to the peat between the pots. In each compartment were placed eight pots of each size and of each soil moisture level, except that no 4-inch pots of wet soil were included. Soil moisture determinations were made at intervals of 24 hours, beginning at the end of the first 48 hours and ending on the eighth day after plunging. The soil from each pot was divided into a 1-inch core and concentric half-inch rings, the number varying with pot size, on each of which soil moisture was determined by drying in an oven at 102 degrees C.

The data resulting from this study, summarized in Table I, show that the soil potted at the low moisture level, regardless of pot size, gained in moisture when plunged in peat at all three moisture levels. Since the percentages of absorption are of the same order regardless of pot size, the differences in thickness of pot wall, or the differences in ratio of surface to volume (1.30 cm^2 to cm^3 in 2-inch pots, and 0.69 cm^2 to cm^3 in the 4-inch pots) seem to have had little effect on moisture movement. The loss of water from the moister soils to the dryer peats illustrates the freedom with which the flow can proceed in either direction.

The periodic determinations of soil moisture content, as typified graphically by the curves for 3-inch pots shown in Fig. 1, show that the transfer of moisture was greatest during the first 48 to 72 hours and was most rapid when the gradients between the inside and outside moisture levels were greatest. Within the pots, at the end of the eighth day, differences in moisture content between the inner core and the outer concentric ring still persisted.

TABLE I—Average Gain or Loss of Moisture in 8 Days by Eight Pots of Soil at Three Moisture Levels When Plunged in Peat at Three Moisture Levels

Moisture Level of Peat (Per Cent)	Soil Moisture Levels					
	Low (7.1 Per Cent)		Medium (14 55 Per Cent)		High (20.8 Per Cent)	
	Soil Moisture After 8 Days (Per Cent)	Gain or Loss (G/Pot)	Soil Moisture After 8 Days (Per Cent)	Gain or Loss (G/Pot)	Soil Moisture After 8Days (Per Cent)	Gain or Loss (G/Pot)
			2-Inch Pots			
161	7.98	+0.8	12.20	-1 32	13.30	-4.24
354	13.90	+5.76	15.90	+2.60	18.0	+0.28
425	14.40	+6.19	16.10	+2.64	18.4	+0.35
			3-Inch Pots			
161	7.63	+ 2.90	12.40	-3.12	15.30	-13.92
354	13.60	+20.61	15.60	+7.34	19.20	-2.38
425	13.50	+20.22	15.90	+7.69	19.70	-3.13
			4-Inch Pots			
161	7.82	+ 7.62	13.10	- 3.88	(Omitted)	
354	13.06	+40 75	16.10	+10.06		
425	15.69	+54.88	17.90	+19.75		

As presented in Table II, where a plus sign denotes a higher and a minus sign a lower moisture content, the outer portion is moister or dryer than the inner core as the movement is inward or outward. The differences within the pots were greatest where the differences between initial soil content and plunging medium had been greatest. Equilibrium within the soil had not been attained. The important consideration is the demonstration that the flow of water through the pot walls was more rapid than that through the soil, a striking commentary on the difficulty of maintaining uniform moisture in staged pots, where there is usually present a considerable difference between soil moisture and the atmosphere surrounding the pot.

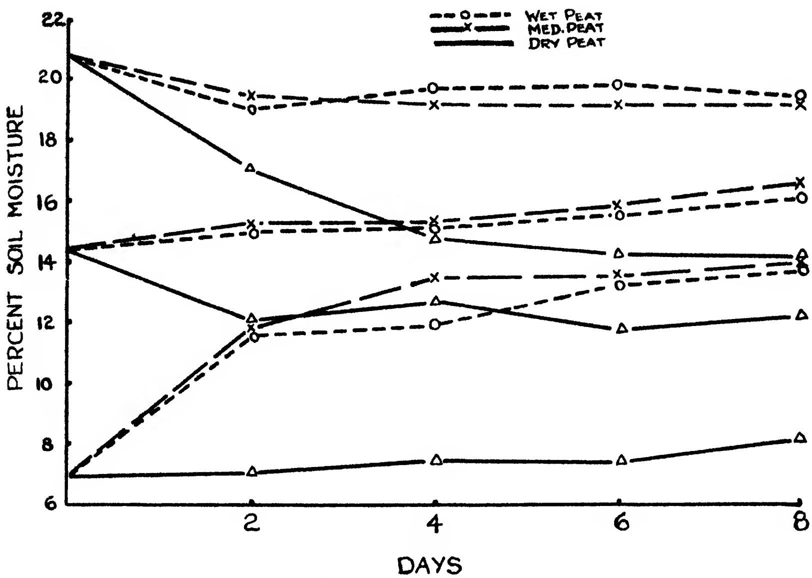

FIG. 1. Movement of moisture between the peat plunging media and the soil held at three moisture levels in pots.

The presence of a growing plant in the pot upsets the equilibrium in moisture, weighting the movement in one direction and raising the query whether the flow inward through the pot walls will suffice for the requirements of the plants. To answer this question 100 Marglobe tomato plants, well established in 2½-inch pots and selected for uniformity of appearance, were immersed in water to saturate the soil, allowed to drain for 24 hours and then divided into five lots of twenty each and distributed as follows: One lot was plunged in each of the three peat compartments previously utilized, one lot was plunged in a similar compartment filled with coarse bank sand, and one lot was placed ("staged") on the surface of a 2-inch layer of sand, in the manner common in greenhouse culture. The bank sand, whose water holding capacity was only 5.3 per cent, was maintained as near saturation as possible; actual determinations varied from 3.9 per cent to saturation. The tests were conducted in August and September, a period of much sunshine and high temperature.

Supplemental water was withheld from five plants in each treatment. In 48 hours the plants staged on sand had wilted seriously, while those plunged in sand remained turgid until the ninth day. Under the circumstances, though positive proof is lacking, assumption of passage of water through the pot walls from the sand to the plunged pots seems warranted. The plants plunged in the low moisture peat did not wilt appreciably until 21 days after they were installed, and after that time they regained their turgidity at night. No wilting occurred at any time in the plants plunged in peat at the medium and high moisture levels. Since "rooting through" the drainage hole in the

pots was rigorously suppressed, it must be assumed that the moister peats supplied water through the pot walls in quantities adequate for the maintenance of the plants in a turgid condition.

TABLE II—DIFFERENCES ON THE 8TH DAY IN THE AVERAGE MOISTURE PERCENTAGES BETWEEN THE SOIL CORE AND THE OUTER ONE-HALF INCH RING OF SOIL IN THE POTS

Peat Moisture Level (Per Cent)	Soil Moisture Levels			Pot Size (Inches)
	Low (7.1 Per Cent)	Medium (14.55 Per Cent)	High (20.8 Per Cent)	
161	+0.13	-0.30	-1.13	2
354	+0.55	0.0	-2.63	2
425	+0.42	-0.36	-2.68	2
161	+0 20	+0.08	-1 09	3
354	+1 96	+0.24	-1.78	3
425	+1.98	+0.14	-1 90	3
161	+0.96	0.0	—	4
354	+2.63	+0.48	—	4
425	+3.68	+0.69	—	4

To determine the water deficit of the plants under the five treatments, the remaining 15 plants in each lot were weighed daily, the loss in weight recorded and sufficient water added to restore the original weight. Since, as will appear presently, the plants developed size differences under the several treatments, the water supplied the larger plants in restoration of original weight would be somewhat less than that applied to the smaller, other things equal. Nevertheless, the differences in water supplied, as shown in Table III, must be interpreted as approximately representing, in a negative manner, the water supplied the pots by the various plunging media. The moisture level of the soil in the pots was apparently high enough to induce moisture flow into the low moisture peat, and probably into the sand. Even in these cases, however, the flow was much less than that from the pots to the air, as shown in the staged plants. Apparently the moisture lost through the walls to the plunging materials reduced the gradient and checked further losses.

During a three-day period of cloudy weather the pots in the medium and the high moisture peats actually gained weight slightly, while those in the dryer peat and the sand continued to lose weight.

The plants plunged in medium and high moisture peats made definitely superior growth, as shown in Table IV. The differences

TABLE III—AVERAGE WEIGHT OF WATER ADDED TO MAINTAIN ORIGINAL WEIGHT OF 15 POTS OF MARGLOBE TOMATO PLANTS UNDER FIVE TREATMENT CONDITIONS FOR 21 DAYS

Treatment	Total Water Added (Gms per Pot)	Average Daily Addition (Gms per Pot)
Plunged in moist sand	101.0	4.81
Plunged in low moisture peat	235.5	11.21
Plunged in medium moisture peat	49.6	2.36
Plunged in high moisture peat	51.4	2.45
Staged on sand (not plunged)	396.9	18.86

TABLE IV—FRESH AND DRY WEIGHTS OF MARGLOBE TOMATO PLANTS MAINTAINED UNDER UNIFORM SOIL MOISTURE CONDITIONS FOR 21 DAYS

Treatment	Total Fresh Weight, 15 Plants (Gms)	Total Dry Weight, 15 Plants (Gms)
Plunged in moist sand	117.5	18.90
Plunged in low moisture peat	125.9	17.90
Plunged in medium moisture peat	193.7	26.20
Plunged in high moisture peat	144.7	21.00
Staged on sand (not plunged)	105.1	16.25

seem too great to be ascribed solely to improved moisture conditions, particularly in view of the rather marked superiority of the plants in the medium moisture peat over those in the high moisture peat. The obvious inference is a movement of nutrients from the peat through the pot walls. Tests of the peats for nitrates by the diphenyl-amine method showed a greater supply in the medium moisture peat than in those held at the high and the low moisture levels.

The decrease in surface area in proportion to cubical contents accompanying an increase in pot size, with the greater thickness of pot walls, raised the question whether larger plants in larger pots would show relationships to media corresponding to those found with small pots. For this phase of the study 72 plants of *Boehmeria macrophylla* G. Don, well established in 4-inch pots, averaging 48 cm in height and growing vigorously, were selected for uniformity from a lot of 400 plants. They were immersed in water until the soil was saturated and then allowed to drain for 24 hours. They were then divided into three lots of 24 plants each; these lots were (a) staged on sand, (b) plunged in wet sand, and (c) plunged in medium moisture peat. The study began October 31 and terminated on January 24, a period when sunlight and evaporation are not high, but when humidity, with artificial heat at 65 to 70 degrees F, is low; nevertheless the period is one when differences would be expected to be small.

Individual weights of pots and contents, taken at the end of the drainage period, were used as datum points to which the weights subsequently found were restored by the addition of water. Weighings were made once each week, except in the case of the pots staged on the sand, where two weighings and two waterings a week were necessary to prevent excessive fluctuations. The additions of water, shown in Table V, are of the same order as those found in the tomato plants in smaller pots, and the proportional relationships between the

TABLE V—WATER ADDITIONS REQUIRED TO MAINTAIN ORIGINAL WEIGHT OF TWENTY-FOUR 4-INCH POTS OF *Boehmeria macrophylla* FOR THE 12-WEEK PERIOD (OCTOBER 31 TO JANUARY 24), UNDER EACH OF THREE TREATMENT CONDITIONS

Treatment	Total Water Added (Gms)	Av Required per Pot (Gms)	Av per Pot per Day (Gms)
Plunged in moist peat	3,683	153	1.80
Plunged in wet sand	9,657	403	4.73
Staged on sand	43,240	1,801	21.19

staged plants and the plunged plants are even greater. Evidently the relationships involved in plunging are not affected materially by the size of the pot, within the limits tested.

Since these plants could not be sacrificed for dry weight determinations, measurements of the three upper pairs of fully developed leaves, produced during the course of the experiment, and of the heights of the plants were recorded. As tabulated in Table VI, the differences between all the means of the leaf lengths and of leaf widths are significant beyond the 1 per cent point. The difference in heights of plants staged on sand and those plunged in sand is not significant, but the difference between the staged and the peat-plunged plants is significant beyond the 1 per cent level and the difference between the two plunging media has a *t* value that is significant between the 5 per cent and the 1 per cent points.

TABLE VI—SUMMARY OF LEAF AND PLANT HEIGHT MEASUREMENTS OF *Boehmeria macrophylla* PLANTS UNDER THREE TREATMENT CONDITIONS FOR 12 WEEKS

Treatment	Average Leaf Length (Cm)	Average Leaf Width (Cm)	Average Plant Height (Cm)
Plunged in moist peat	27.80 ±3.51	4.59 ±0.64	57.88 ±4.35
Plunged in wet sand	24.35 ±2.86	3.97 ±1.11	53.73 ±5.83
Staged on sand	21.41 ±2.18	3.59 ±0.36	51.35 ±4.66

Movement of nutrients through the pot wall was studied with plants plunged in a bed 3½ feet wide and 32 feet long. This contained peat which had been used as a plunging medium for about four years and had been reduced to rather small particles. This bed was partitioned by boards into eight beds, each 4 feet long. These smaller beds were considered as two blocks, within which four treatments were located at random. These treatments were: (a) an unfertilized check, (b) a basic complete nutrient containing 17.04 gms nitrogen from $NaNO_3$ and $(NH_4)_2SO_4$, 17.04 gms phosphorus from superphosphate and 8.52 gms potash from KCl, applied in 10 gallons of solution to the peat and thoroughly mixed with it to a depth of 6 inches, (c) twice the basic amount and (d) three times the basic amount of nutrients in the same volume of solution. Three plant species were used as test subjects; *Brassica oleracea* var. Jersey Wakefield, *Withania somnifera* (L.) Dunal, and *Salvia splendens* Ker-Gawl. In each of the eight beds 20 uniform plants of each species, established in 3-inch pots in ordinary potting soil, were plunged.

No water was added directly to the soil in the pots, and since the drainage holes had been covered with paraffined paper, all the water required by the plants was supplied through the pot walls from the peat. Water was applied to the peat at irregular intervals, but never in sufficient quantity to cause saturation. The average of seven moisture determinations during the course of the test (June 24 to October 10) was 220 per cent. Though this was below 50 per cent of the moisture holding capacity of the peat, it sufficed to prevent wilting except in a few large plants on a few days of extremely high tempera-

tures. The total application of water during the 108 days was 1.43 gallons per square foot, applied in unequal portions at approximately 5-days intervals.

TABLE VII—SUMMARY OF HEIGHT AND WEIGHT DATA OF PLANTS PLUNGED IN PEAT BEDS AT FOUR NUTRIENT LEVELS

Treatment	Plants Surviving (Number)	Average Height (Cm)	Average Fresh Weight (Gms)	Average Dry Weight (Gms)
Brassica oleracea Var. Jersey Wakefield				
No fertilizer	35	————	2.02	0.456
Basic nutrient	31	————	6.71	1.497
Double nutrient	17	————	8.77	1.697
Triple nutrient	30	————	8.83	1.648
Withania somnifera				
No fertilizer	39	5.26 ±1.73	1.07	0.179
Basic nutrient	40	10.04 ±2 68	2.86	0.509
Double nutrient	39	11.18 ±3.07	2.95	0.558
Triple nutrient	40	14.42 ±3.97	3.57	0.741
Salvia splendens				
No fertilizer	40	29.42 ±6.53	7 85	1.60
Basic nutrient	38	40.25 ±7.57	18.80	2.89
Double nutrient	37	38.77 ±6.35	22.24	3.31
Triple nutrient	31	29.13 ±7 09	21.51	3.23

The salvia plants receiving the basic nutrient and its double made significantly more growth than those in the check plots (cf. Table VII). Comparison of their height means gives a *t* value of over 6.0. The plants in the triple nutrient plots evinced symptoms of over feeding in the very dark green of their leaves and the shortness of their internodes. Though not significantly taller than the check plants, their weights were much greater, and were comparable to those of the other plants in fertilized peat. The triple application was approximately at the rate of 3,000 pounds per acre. The higher mortality in the triple application may have been due to over-fertilization.

The withania plants showed definite increases from the fertilizer applied to the plunging media. The *t* values for comparison of the unfertilized plants with any of the fertilized lots are over 9.0, or well beyond the 1 per cent point. Probably because of the high temperatures and dry atmosphere of the greenhouse, the cabbage plants made very poor growth and their mortality rates were higher. Their type of growth made height measurements meaningless, but the weights showed marked differences between the fertilized and unfertilized plunging media. Whether all three nutrient elements moved through the pot walls cannot be stated, but it is evident that some did.

These experiments illustrate the difficulties attendant on growing plants in staged pots. The ordinary flower pot seems to serve merely as a soil container; so far as moisture is concerned it affords little protection and might almost be considered a wick, since it transmits moisture more rapidly than the soil. Fluctuations in moisture supply of staged potted plants are inevitable, and the total water consumption their use entails is very great. The waterings, necessarily frequent, needed to replace the lost moisture increase the compaction of the top-

soil in the pot, rendering uniform watering increasingly difficult. Over a long period, under these conditions, leaching of nutrients must be considerable. Soil compaction and leaching of nutrients necessitate repotting even of plants which have reached their full size. Plunging, particularly in a medium such as peat, eliminates much, if not all, of the need of direct watering of the soil in the pots and, through reversing the direction of movement, obviates much of the difficulty involved in the care of staged potted plants. It reduces to a small fraction the time necessary for watering, favors uniformity of supply to all pots in accordance with their individual needs, and withal produces better plants.

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Persistence of the Moisture Conserving Effect of Methylcellulose in Soil

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In previous experiments (1) using aqueous dispersions of methylcellulose, it has been shown that this material is able to restrict considerably the water loss from soils and plants. It seemed, however, desirable to simplify this method of soil treatment, especially in view of using methylcellulose in field practice, and to find out, whether applications of the commercially available, anhydrated product which is fibrous and cotton-like, may successfully replace those of dispersions, herewith eliminating the time engaging preparatory procedure.

The dry fiber of methylcellulose is not hygroscopic. Only when hydrated the fibers form a colloidal dispersion which is hydrophilic. The effect of the dry material, when mixed into soil and supplied with water, was tried out and compared with that of adequate dispersions.

Experiment I

Method:—400 gms of air-dry composted greenhouse soil were filled into stoppered, 4-inch standard clay pots. To the control soil and to that containing 1.6 gms of dry methylcellulose 40 per cent moisture was added in form of tap water, and to another group equal allotments of moisture and methylcellulose were supplied in dispersed form. Each experimental group consisted of 10 fallowed pots. One series was planted with beans. The daily water loss of each pot was recorded and replaced. In the series with bare soils, periods of suspended water supply were introduced.

Results:—The results are shown in Table I. During the period of the first 20 days following treatments the effect of the fiber application was small, about 16 per cent which was only about a third of that of the dispersion. However, after a further 50-day period of alternately wetting and drying the soil in 6-day intervals, the methylcellulose fiber made up for its initial set back. During a following period of water

TABLE I—The Effect of Equal Amounts of Methylcellulose Applied in Aqueous Dispersion and in Its Commercial Fibrous Form to Soil

Treatment	Controls	160 Gms of 1 Per Cent Dispersion	1.6 Gms Fiber	Exp. Period of Daily Water Replacements
A. Bare Soil				
Total amount of water loss—gms.	6,326	3,632	5,323	May 20 to Jun 8
Reduction in water loss—in per cent	—	43	16	May 20 to Jun 8
Total amount of water loss—gms	1,641	992	1,075	Jul 13 to 17
Reduction in water loss—in per cent	—	40	35	Jul 13 to 17
Total amount of water loss—gms.	1,907	1,255	1,259	Jul 27 to Aug 1
Reduction in water loss—in per cent.	—	34	34	Jul 27 to Aug 1
B. Soil Planted With Beans				
Total amount of water loss—gms.	9,602	6,301	7,744	May 20 to Jun 8
Reduction in water loss—in per cent.	—	34	19	May 20 to Jun 8

replacements the rates of water loss resulting from both treatments were almost equal, showing a reduction in water loss of about 34 per cent each, the soil treated with dispersion having lost some of its initial effect in the meantime.

In soil planted with beans, methylcellulose fiber showed an immediate effect of only 19 per cent while the treatment with dispersion resulted in 34 per cent reduction in water loss. When a light field soil was used instead of the composted soil, the incorporation of methylcellulose fiber was less effective. Even after a 40-day period of daily water replacements, the moisture conserving power remained small, —3 to 13 per cent, — in consequence of the larger pores of the soil, which failed to hold water sufficiently to give the fibers a chance to dissolve completely.

Experiment II

Those preliminary observations seemed to indicate that applications of the dry fiber may be successful, if certain conditions and enough time were offered to transform the material in the soil from its anhydrated form into a sol, and it was assumed that such an action may take place in the soil under the influence of weathering. In order to test this hypothesis, the following experiments were carried out.

Method:—Standard size No. 10 tin cans were filled with 1200 gms of air-dry composted greenhouse soil. A hundred of those cans were left as controls. The cans of one series, including controls and treated soil, were provided with drainage holes at the bottom, while in another series they were left without perforation. One group was supplied with 25 gms Methocel fiber of the 400 cps. viscosity grade, another with 12 gms of the 4000 cps. grade, and the crumbled material thoroughly mixed with the soil in each can. These prepared and numbered cans were placed in a coldframe the first part of November where they remained until June, after the accumulated surface water from snow-ice and rain had disappeared. The soil moisture of each can was then determined by weight.

Results:—In Table II the moisture content after the 7 months' period of exposure is shown in the various experimental groups. The figures indicating the moisture retention resulting from treatments are compiled for both viscosity grades, since their effects were fairly conformable differing by only less than 1 per cent.

The differences in soil moisture between the controls and the

TABLE II—Moisture Conservation in Wintered-over Soil

Number of Cans	Treatment in Fall	Average Soil Moisture in Spring—in Per Cent
	Wintered-over Soil Drained	
70	Controls	5
100	Methocel fiber	16
	Wintered-over Soil Without Drainage	
30	Controls	23
30	Methocel fiber	29

Methocel-treated soil are considerable. They are greater in the group of perforated cans than in that left without drainage. In fact, the drained soil had more than 3 times as much moisture after wintering-over when treated than the controls, while the undrained, but treated soil surpassed the moisture content of the controls by only about 6 per cent.

Experiment III

Additional experiments with these wintered-over soils were carried out in the greenhouse, in order to test their efficiency in reducing water loss when planted.

Method:—The bottom holes of the perforated cans were sealed. All cans were adjusted to 25 per cent soil moisture by adding the necessary amount of tap water. They were divided into four experimental sets and planted with seedlings of cabbage, corn, beans and tomatoes. Some comparable groups of bare soil were also tested. Ten cans were used in each group of treatment whether planted or left bare. The water loss from each can was daily recorded and replaced.

Results:—The data in Table III show the resulting differences in water loss between methylcellulose-treated and untreated soil during periods of daily water replacements. It is apparent, that in all instances bare soil responded to the treatments with a higher degree of moisture retention than the planted soil, being subjected to water loss only through evaporation. The water loss-reducing effect of methylcellulose fiber in drained, bare soil ranged between 35 and 70 per cent, while in planted soil the treatments resulted in decreasing water loss from 33 to 47 per cent, with respect to the single groups. The treatments

TABLE III—Water Loss Rates of Planted and Bare Soil After Exposure to Weathering During Winter. (Figures are Totals for 10 Cans of Each Group)

Planted	Treatment	Experiment Period	Total Water Loss (Gms)	Reduction in Water Loss (Per Cent)	Left Bare	
					Total Water Loss (Gms)	Reduction in Water Loss (Per Cent)
		A. Wintered-over Soil With Drainage				
With Cabbage	Controls	May 30 to Jul 28	34,055	—	17,871	—
	25 gms fiber 400 cps	May 30 to Jul 28	21,119	38	5,465	70
With Corn	Controls	Jun 20 to Jul 29	21,412	—	12,196	—
	25 gms fiber 400 cps	Jun 20 to Jul 29	13,436	37	———	—
	12 gms fiber 4000 cps	Jun 20 to Jul 29	13,993	35	6,624	45
With Beans	Controls	Jun 21 to Jul 30	27,407	—	12,196*	—
	25 gms fiber 400 cps	Jun 21 to Jul 30	14,505	47	———	—
	12 gms fiber 4000 cps	Jun 21 to Jul 30	18,399	33	7,970	35
		B. Wintered-over Soil Without Drainage				
With Tomatoes	Controls	Jun 22 to Jul 31	22,040	—	———	—
	25 gms fiber 400 cps	Jun 22 to Jul 31	11,017	50	———	—
	Controls	Jun 24 to Aug 2	29,853	—	10,633	—
	25 gms fiber 400 cps	Jun 24 to Aug 2	11,810	60	4,014	62

*For the control cans of the bare series for beans the same value of the total amount of water loss was taken as for corn. This was necessitated in consequence of a shortage of wintered-over control cans.

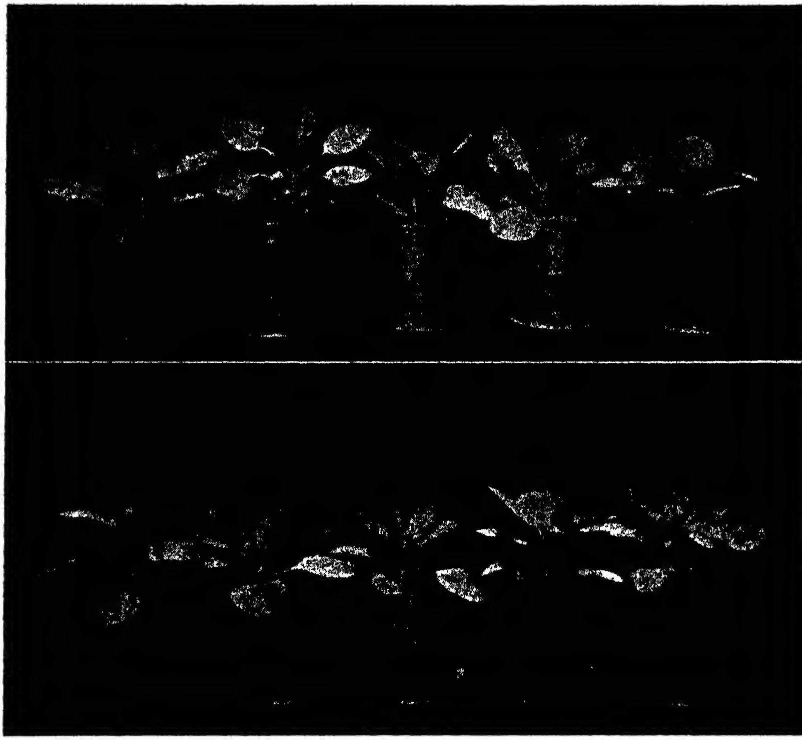

FIG. 1. Cabbage plants 6 weeks old. (Above) soil treated with methyl-cellulose fiber and wintered-over in cans with drainage. (Below) controls, soil wintered-over, but not treated.

in wintered-over soil without drainage caused about 50 and 60 per cent reduction in water loss during the growth of tomatoes which developed unusually slowly and not uniformly in both controls and treated soil. All other plants grew well, although a slight retardation of growth in the treated soil was observable. Figs. 1 to 4 illustrate the average type of the plants' appearance during the experiment.

SUMMARY AND DISCUSSION

The results from this study confirm the general favorable effect of methylcellulose in potted soil with regard to its moisture conserving influence. Methylcellulose fiber, the commercially available anhydrated product, can be successfully substituted for its dispersions, offering a simplified and more practical method of application. Nature takes care of preparing gradually the hydrolyzed state of the fibers during weathering or wintering-over, making Fall treatments effective in Spring and the soil ready for planting. With proper choice of the amount of methylcellulose and its viscosity grade, giving due regard to the water holding capacity of the soil and the prevailing

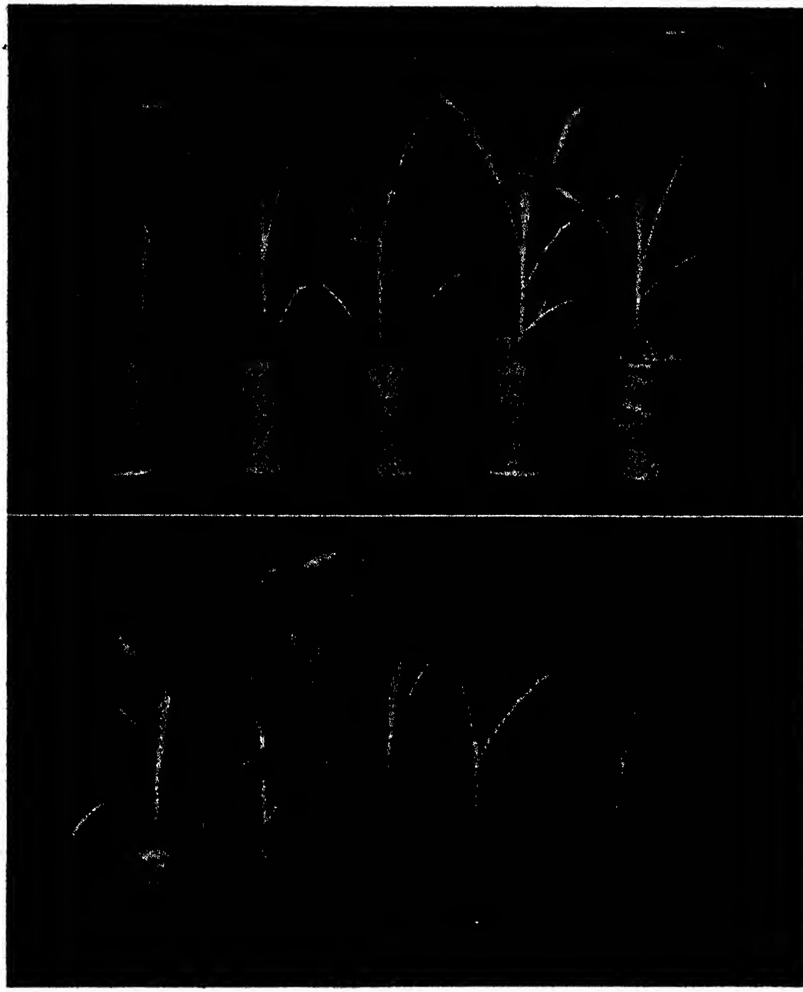

FIG. 2. Corn plants 4 weeks old. (Above) soil treated with methylcellulose fiber and wintered-over in cans with drainage. (Below) controls, soil wintered-over, but not treated.

conditions of moisture and temperature, this method of soil treatment may possibly be successfully used in orchards and fields.

The amount of fiber applied to the wintered-over soil is four and eight times greater than the dosage previously used in dispersions. An excess of the substance seemed desirable to be applied at the start of the experiment. The resulting effect apparently substantiated this assumption, since the magnitude of moisture retention in the wintered-over soil, expressed in per cent of water-loss reduction, equalized the effects usually obtained from a one or two per cent dispersion treatment, ranging from about 35 to 40 per cent.

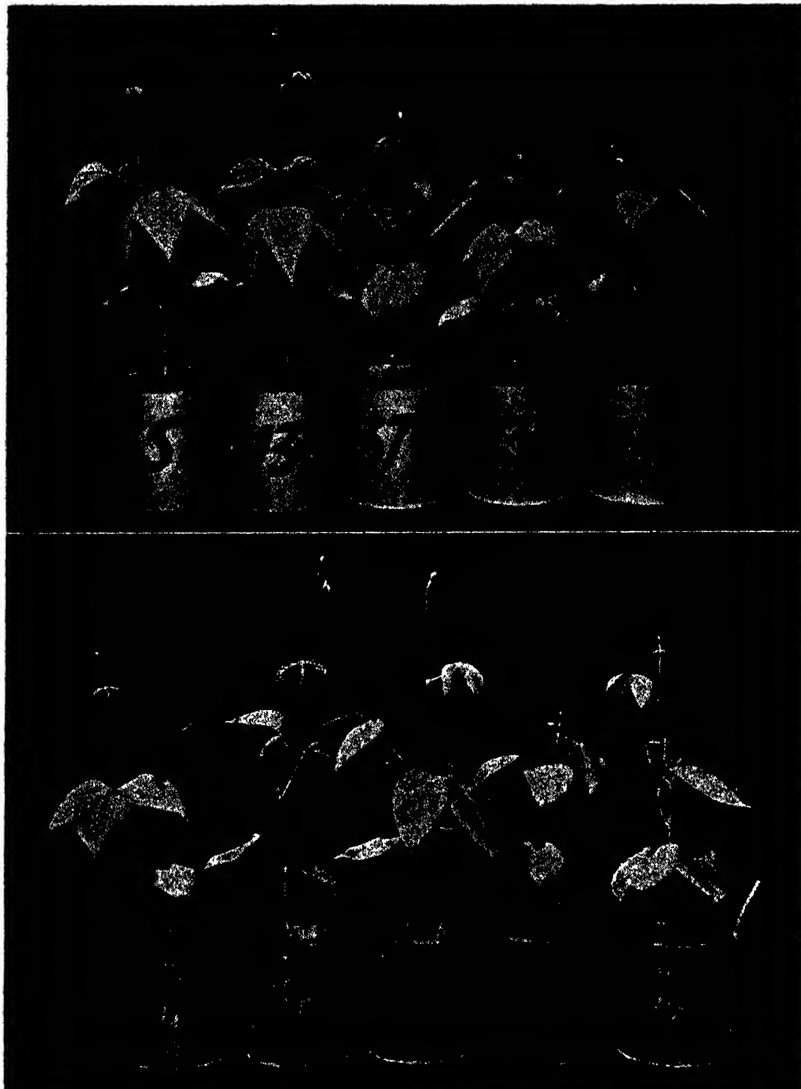

FIG. 3. Bean plants 3 weeks old. (Above) soil treated with methylcellulose fiber and wintered-over in cans with drainage. (Below) controls, soil wintered-over, but not treated.

Pending further investigations, the great versatility of water soluble methylcellulose may be emphasized. The property of its aqueous dispersions, to gel upon heating and to reverse upon cooling, is inverse to the sol-gel transformation of agar and gelatine, and may be used advantageously. Besides, wet films of dispersions yield upon dehy-

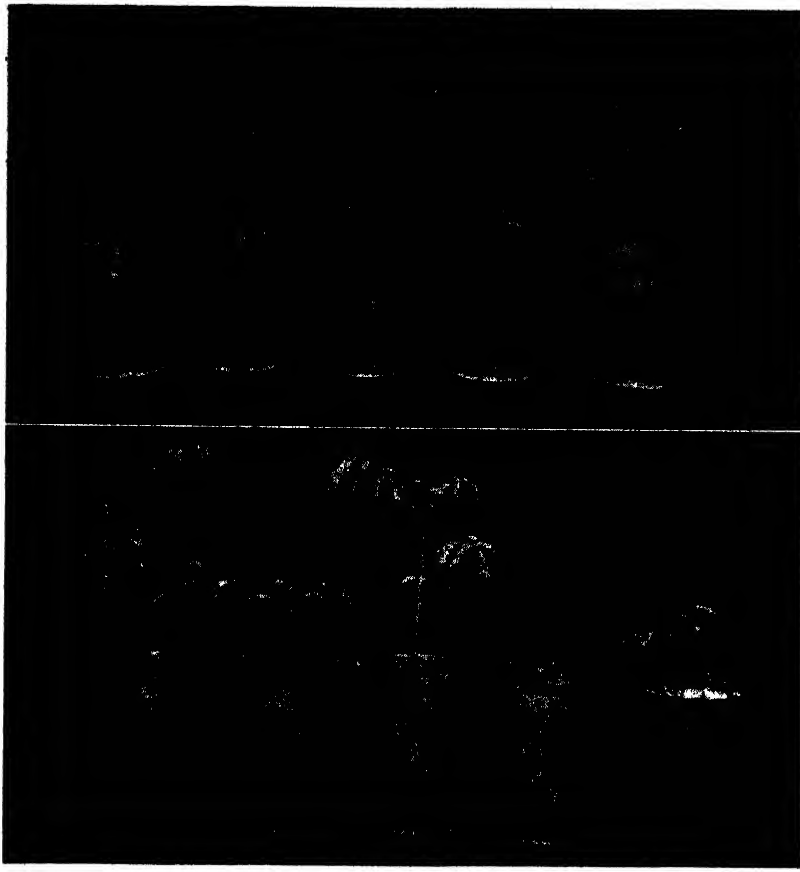

FIG. 4. Tomato plants 3 weeks old. (Above) soil treated with methyl-cellulose fiber and wintered-over in cans without drainage. (Below) controls, soil wintered-over, but not treated.

dration films of high tensile strength, resembling cellophane paper in their appearance.

Those characteristics may be utilizable in plant sciences and related fields for various purposes, for example: Tree wound dressing; protective coating of seeds and fruits against insects; preventive for root-drying at transplanting; as a culture medium for bacteria, which may differentiate them in other ways than usual; and for sterile tissue culture.

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The Use in Horticultural Publications of Black and White Prints from Kodachrome Transparencies

By WESLEY P. JUDKINS and JOHN G. TOLK, *Ohio Agricultural Experiment Station, Wooster, O.*

MANY professional horticulturists take Kodachrome transparencies to use at meetings when discussing experimental results or horticultural practices. These pictures, if carefully taken, have a further value which does not seem to have been fully appreciated. Black and white prints made from high-quality Kodachrome transparencies are satisfactory for use in publications.

Large film plates may record somewhat finer details than are possible on 35-mm Kodachrome films. In a majority of cases, however, carefully taken Kodachrome transparencies will give sharp black and white prints which are suitable for use in many types of publications. Black and white films used with a Speed Graphic camera as discussed in a recent article (1) are more useful under poor light conditions than Kodachrome but most outdoor pictures can be taken when the sunlight is suitable for colored film. Kodachrome for use with artificial light can of course be exposed indoors at any time when proper lighting equipment is available.

Fig. 1 illustrates the contrast and detail obtained when Kodachrome, and black and white film were used under identical con-

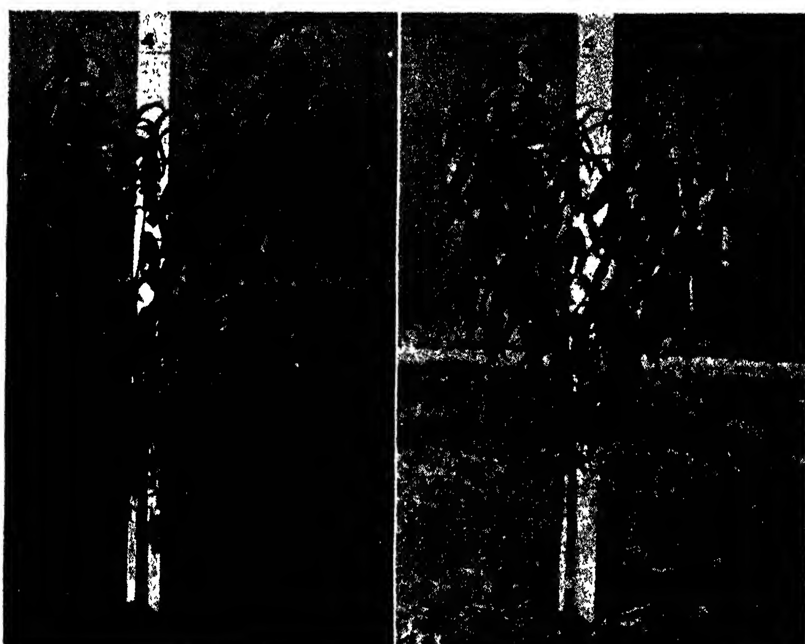

FIG. 1. Peach tree taken at distance of 10 feet with (left) Tri x Pancromatic film (4x 5-inch plate) and (right) Kodachrome 35-mm daylight film.

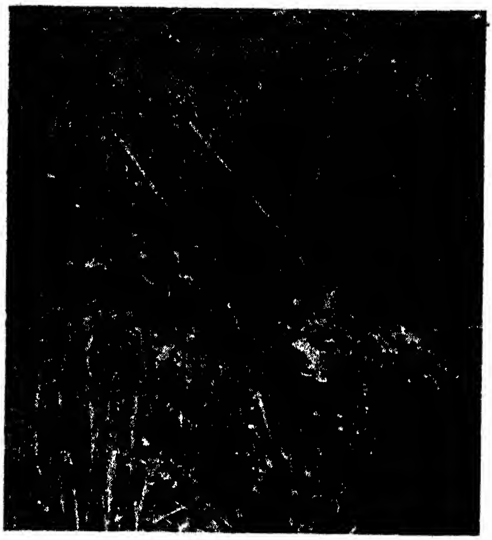

FIG. 2. Raspberry plants showing winter heaving. Kodachrome 35-mm daylight film.

ditions of light and distance. The picture at the right was taken with a Kodak 35 camera using Kodachrome K 135 daylight film at F-8, $^1/_{60}$th of a second exposure. The black and white picture of Fig. 1 (left) was taken with a Speed Graphic camera (4x5-inch plate) Tri x Panchromatic film at F-18, $^1/_{50}$th of a second exposure.

Fig. 2 was taken with Kodachrome film at a distance of about 5 feet from the raspberry bushes. With suitable lenses, colored pictures may be taken at distances of about 1 foot from the subject. Figs. 3 and 4 furnish additional evidence of the range of adaptability of Kodachrome film in taking pictures which are of interest to horticulturists.

Instructions for making black and white prints from Kodachrome transparencies (2) indicate that it is preferable to use panchromatic film. The contrast of Kodachrome is usually somewhat higher than that of the original scene and therefore it may be desirable to lower the contrast by shortening the time of development. The processing should be in Kodak D-76 or DK-50 or similar developer depending on the particular type of film being used.

FIG. 3. Airplane view showing spotty soybean crop following orchard removal. Picture taken with Kodachrome 35-mm daylight film.

FIG. 4. Peach fruit showing cracking. Kodachrome artificial light film.

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The Response of Three F_1 Lines and Ten Strains of Tomatoes to Two Distinct Soil Types[1]

By RUSSELL E. LARSON and WILLIAM L. MARCHANT, *Rhode Island Agricultural Experiment Station, Kingston, R. I.*

IT HAS long been known that advantageous results are obtained by the use of certain hybrid agronomic and horticultural crops. As an outstanding example, hybrid corn is superior in many respects to open-pollinated strains. Tomato crosses are also known to produce F_1 lines which may be better in one or more respects to either parent and to commercial varieties. However, irregardless of the evident value F_1 lines of tomato hybrids may have, they have not been adopted commercially except by a few greenhouse tomato growers. Undoubtedly the expense of this type of seed influences the lack of popularity of tomato hybrids but it should not be wholly responsible for their absence from the market. It is probable that varied responses on different soil types has caused some doubt as to their potential value.

The purpose of this study was to determine the response of tomato varieties and F_1 lines of tomato hybrids to different soil types. Comparisons were made among the commonly grown strains in this locality with three F_1 lines which had been previously tested and found to have good characteristics of earliness, yield, and marketability.

No extensive literature review is given in this report except for a few pertinent articles which are in agreement with or contradictory to material here presented. For a bibliography of literature on the subject of F_1 horticultural crops the reader is referred to the publications of Larson and Currence (2) and Powers (4).

Nine varieties of tomatoes plus one greenhouse selection and three F_1 lines of tomato hybrids were grown in randomized triplicated plots at two Rhode Island locations. The three F_1 lines had, in preliminary experiments, given indications of superiority to the inbred varieties tested. The varieties tested comprise those strains most popular with the Rhode Island tomato growers. No effort was made to compare the F_1's with their parents.

Tests were conducted in the Hillsgrove market garden area where a light sandy soil type (Merrimac Fine Sandy Loam) is predominant and at Newport on a relatively heavy loam soil (Bernardston Loam). To simplify the discussion, reference is made in the text to the Hillsgrove and Newport locations which refer directly to the Merrimac Fine Sandy Loam and Bernardston Loam respectively. An application of 1500 pounds of a 5–8–7 analysis chemical fertilizer plus 8 tons of manure per acre were applied in both field tests. Plants were spaced 4 feet by 4 feet. Each plot at Hillsgrove contained 11 plants while each plot at Newport consisted of 8 plants. The plants were started in the greenhouse on April 16, and transplanted to the field May 29–31.

There had been ample moisture during the spring and the soils were in a good friable condition at the time of transplanting. However,

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[1]Contribution No. 644 of the Rhode Island Agricultural Experiment Station, Kingston, R. I.

rainfalls throughout most of the summer were decidedly below normal and the plants on the light sandy soils were retarded somewhat from lack of ample moisture. The total precipitation at Hillsgrove for the months of June, July, August and September was 2.10; 3.91, 1.89 and 1.37 inches respectively whereas Newport precipitation was 0.68, 2.49, 2.59 and 1.21 inches respectively. Because of the higher moisture holding capacity of the heavy loam soil the total precipitation appeared to be ample for full development of the tomato plants.

Mean temperatures at the two locations were approximately the same. Unfortunately soil temperatures were not recorded. However the sandy soil appeared to be noticeably warmer on cloudless days.

A count was kept of all tomatoes harvested as well as the number of marketable fruits. Early yields were based on the quantities harvested through August 12, at which date the price per bushel had dropped below three dollars.

Records on early yield, total yield, marketable yield, and fruit size were analyzed by Fisher's analysis of variance method. An attempt was made to determine the interaction of varieties by locations and certain differential responses are given in the text.

Experimental Results — Early Yields

As might be expected early yields were greater on the light sandy soils of the Hillsgrove area. Each of the three F_1 lines significantly exceeded the early yields of the varieties. The early yield of Earliana x Redcap was 111.8 bushels per acre greater than the earliest variety, Redcap. Waltham x Earliana, and Valiant x Earliana also produced significantly greater early yields of 33.1 and 41.8 bushels per acre respectively. The average early yield for all strains was 102.7 bushels per acre.

The average early yield of all strains at Newport was 78.5 bushels per acre. This is a significantly smaller early yield than that obtained at Hillsgrove. F_1 lines Earliana x Redcap, Waltham x Earliana, and Valiant x Earliana exceeded the highest early yielding variety Valiant by 21.9, 8.8, and 42.3 bushels per acre respectively. It should be noted that the difference in early yield between F_1 lines Waltham x Earliana and Valiant x Earliana was 8.7 bushels at Hillsgrove in favor of the latter. The Newport results showed a difference of 33.5 bushels per acre between the two lines and again favored the Valiant x Earliana line. The difference between differences is 24.8 bushels per acre which exceeds the .01 level of significance indicating that these two F_1 lines did not respond the same to the two different soil types. Similar differential responses may be noted in Table I.

Total Yields

Total yields in bushels per acre are presented in Table II. As stated previously the plants growing in the rapidly drained sandy soils were retarded, whereas those planted in the heavier loam soils at Newport, which are retentive of moisture, developed to a much greater extent and thus aided in producing much greater yields. The F_1 lines in

TABLE I—EARLY YIELDS IN BUSHELS PER ACRE OF THREE F_1 LINES AND TEN STRAINS OF TOMATOES GROWN ON TWO RHODE ISLAND SOILS

Variety or F_1 Line	Merrimac Fine Sandy Loam (Hillsgrove)	Bernardston Loam (Newport)	Mean
Earliana × Redcap	215.3	110.3	162.8
Waltham × Earliana	136.6	97.2	116.9
Valiant × Earliana	145.3	130.7	138.0
Greenhouse Selection 1–43	179.8	170.1	174.9
Scarlet Dawn	81.2	79.7	80.4
Comet	90.9	69.0	79.9
Marglobe	52.5	39.8	46.1
Valiant	92.8	88.4	90.6
Rutgers	29.6	25.3	27.4
Waltham	72.9	51.0	61.9
Redcap	103.5	59.8	81.6
Bestal	59.3	59.3	59.3
Stokesdale	75.3	39.8	57.5
Mean*	102.7	78.5	—
Significant difference	12.9	10.7	8.2
Highly significant difference	23.9	14.4	11.1

*Significant difference = 2.2 bushels; highly significant difference = 4.4 bushels. Interaction of stations × varieties: significant difference = 11.7 bushels; highly significant difference = 15.6 bushels.

the Hillsgrove test were not significantly different in total yield from the other varieties excepting Redcap and Bestal which produced significantly greater total yields than either F_1 line.

Under the prevailing conditions of Newport, however, the three F_1 lines significantly outyielded all varieties excepting Bestal, and did not differ significantly from this variety.

TABLE II—TOTAL YIELDS IN BUSHELS PER ACRE OF THREE F_1 LINES AND TEN STRAINS OF TOMATOES ON TWO RHODE ISLAND SOILS

Variety or F_1 Line	Merrimac Fine Sandy Loam (Hillsgrove)	Bernardston Loam (Newport)	Mean
Earliana × Redcap	476.3	1056.2	766.3
Waltham × Earliana	510.3	1244.2	877.2
Valiant × Earliana	422.8	1070.8	746.8
Greenhouse Selection 1–43	456.8	618.8	537.8
Scarlet Dawn	409.6	844.0	626.9
Comet	320.8	860.2	590.5
Marglobe	482.8	742.0	612.4
Valiant	464.9	889.4	677.2
Rutgers	439.0	740.3	589.7
Waltham	505.4	788.9	647.2
Redcap	609.1	962.3	785.7
Bestal	648.0	1190.7	919.3
Stokesdale	503.8	973.6	738.7
Mean*	480.7	921.6	—
Significant difference	129.8	242.0	137.3
Highly significant difference	181.8	338.7	183.9

*Significant difference = 54.0 bushels; highly significant difference = 72.4 bushels. Interaction of stations × varieties: significant difference = 194.1 bushels; highly significant difference = 260.1 bushels.

Since the interaction of "stations by varieties" was significant it indicated that all strains did not respond the same under both soil conditions. In Table II it may be seen that Waltham x Earliana, at Hillsgrove, yielded 510.3 bushels as compared to the 1244.2 bushels produced at Newport. The variety Redcap produced 609.1 and 962.3 bushels per acre at Hillsgrove and Newport respectively. The differences then were 609.1 − 510.3 = 98.8 and 962.3 − 1244.2 = −281.9.

The difference between differences would then be 98.8 − (−281.9) = 380.7 bushels which is above the .01 level of significance.

As an average of both locations Bestal produced the greatest total yield. However, the F_1 line Waltham x Earliana averaged 877.2 bushels per acre which is not significantly different from the average total yield of the afore mentioned variety. From an economic standpoint it will be later noted that the marketable yield was low for Bestal and relatively high for Waltham x Earliana. The average total yields of the three F_1 lines exceeded that of most of the varieties, in many cases by a significant amount.

Fruit Size

Average fruit sizes, in ounces, are presented in Table III. The very large average size differences of all varieties at Hillsgrove and Newport are of considerable interest. They averaged 3.32 and 4.47 ounces per fruit for the two locations respectively which is a difference of 34.6 per cent and is highly significant. In general the fruits maintained the same values in relation to each other, although their absolute values differed considerably. However, this was not true in all instances. For example, Valiant and Valiant x Earliana averaged 4.00 and 3.04 ounces per fruit respectively at Hillsgrove. The same strains averaged 4.80 ounces each at Newport. In this case the difference between differences is 0.96 ounces and exceeds the .01 level of significance. Thus for this character, too, it is evident that certain strains responded differently to the loamy and sandy soils.

TABLE III—Average Size of Fruit in Ounces of Three F_1 Lines and Ten Strains of Tomatoes on Two Rhode Island Soils

Variety or F_1 Line	Merrimac Fine Sandy Loam (Hillsgrove)	Bernardston Loam (Newport)	Mean
Earliana × Redcap	2.88	4.32	3.60
Waltham × Earliana	2.40	3.84	3.12
Valiant × Earliana	3.04	4.80	3.92
Greenhouse Selection 1-43	2.56	2.88	2.72
Scarlet Dawn	4.00	4.80	4.40
Comet	2.56	3.52	3.04
Marglobe	4.48	5.12	4.80
Valiant	4.16	6.08	5.12
Rutgers	5.28	5.76	5.52
Waltham	2.56	3.36	2.96
Redcap	3.68	5.28	4.48
Bestal	2.24	3.04	2.64
Stokesdale	3.36	5.28	4.32
Mean*	3.32	4.47	—
Significant difference	0.54	0.41	0.32
Highly significant difference	0.73	0.56	0.43

*Significant difference = 0.12 ounces; highly significant difference = 0.17 ounces. Interaction of stations × varieties: significant difference = 0.45 ounces; highly significant difference = 0.61 ounces.

Average fruit size of the three F_1 lines was generally smaller than that of the varieties, the four exceptions being Greenhouse Selection 1–43, Comet, Waltham, and Bestal. Since the F_1 inheritance of small fruit size is intermediate with a tendency toward the smaller sized parent (3) it would be expected that the F_1 lines would not average much more per fruit than their smaller parent. To be acceptable to local markets tomato fruits must average about 3 ounces.

Earliana x Redcap and Waltham x Earliana did not produce fruits averaging this large at Hillsgrove. However, as noted from the table on marketable yields, they still maintained a high marketable average. This may be explained when one considers that those fruits counted as non-marketable were primarily fruit affected with blossom end rot and thus were in most instances undeveloped or dehydrated and extremely light in weight. Since they were counted and weighed together with the normal fruits they undoubtedly influenced fruit size values adversely.

Total Marketable Yields

Total marketable yields are presented in Table IV. The analyses of variance gave significant F values for varieties at both stations and the combined analysis showed significant F values for varieties, stations, and the interaction of varieties by stations.

TABLE IV—Total Marketable Yields in Bushels Per Acre of Three F_1 Lines and Ten Strains of Tomatoes on Two Rhode Island Soils

Variety or F_1 Line	Merrimac Fine Sandy Loam (Hillsgrove)	Bernardston Loam (Newport)	Mean
Earliana × Redcap	330.5	913.7	622.1
Waltham × Earliana	369.4	1083.8	726 6
Valiant × Earliana	340.2	967.1	652.6
Greenhouse Selection 1-43	233.3	432.5	332.9
Scarlet Dawn	345.1	767.9	556.5
Comet	233.3	743.6	488.4
Marglobe	437.4	685.3	561.3
Valiant	432.5	826.2	629 3
Rutgers	393.7	675.5	543.6
Waltham	379.1	714.4	546.7
Redcap	442.3	865.1	653.7
Bestal	393.7	918.5	656.1
Stokesdale	369.4	928.3	648.8
Mean*	361.5	809.4	——
Significant difference	139.2	209.0	122.9
Highly significant difference	——	284.1	164.7

*Significant difference = 48.6 bushels; highly significant difference = 64.6 bushels. Interaction of varieties × locations: Significant difference = 174.0 bushels; highly significant difference = 233.3 bushels.

The number of marketable fruits at Hillsgrove were in most cases considerably less than those from Newport. This was primarily due to the differences in average fruit size. The amount of blossom end rot that affected the fruit at the former station reduced the marketable yields. This condition is closely correlated with the soil moisture (5), dry soil favoring the development. Since a summer drought was encountered the early types such as the three F_1 lines were observed to be greatly reduced in quantity of marketable fruits. An exception to this was Valiant, which lost a relatively minor number of fruits due to blossom end rot. The indeterminate late maturing varieties also lost considerable fruit due to blossom end rot but produced the greatest total marketable yields.

Loss of fruit due to diseases was relatively minor at Newport. Fruits at this location were discarded on the basis of small fruit size or roughness. The F_1 line Waltham x Earliana produced a total marketable yield significantly exceeding all varieties excepting Bestal

and Stokesdale. Waltham x Earliana exceeded the two afore mentioned varieties by 165.3 and 155.5 bushels per acre respectively which gives odds of 8 to 1 and 6 to 1 respectively that these differences are significant. Earliana x Redcap and Valiant x Earliana exceeded most of the varieties by a significant amount and were not significantly different from the remainder.

The extreme difference in average marketable yields of the two stations is primarily due to the difference in moisture holding capacities of the two soil types. Undoubtedly, the difference would have been much less had uniform soil moisture conditions been maintained by controlled irrigation.

Due in part to conditions just enumerated, the varieties and lines did not respond the same at both locations. Several differential responses as measured by total marketable yields may be noted in Table IV.

Economic Applications

Harvesting began at Hillsgrove on July 26, at which time tomatoes were being sold at $7.00 to $10.00 per bushel. The second harvest was made on August 4 and had a value of $5.00 to $7.00 a bushel. On August 12, a third harvest was made. Tomatoes were then valued from $2.50 to $3.50 per bushel. Both Newport and Hillsgrove market gardeners service the same markets so the values received are constant for both locations. However, harvesting did not begin at Newport until August 4 and the monetary returns on early yields were less, due to the smaller harvests.

Table V gives a varietal comparison of the calculated monetary returns from early and total yields at Newport and Hillsgrove. Setting a conservative value of $4.00 per bushel on early yields, it will be noted that the three F_1 lines would have brought much greater returns than the varieties. Similarly the F_1 lines at Newport would have brought higher returns on early yields.

If an average price of $1.00 per bushel is set on marketable fruits

TABLE V—A Comparison of Yields and Calculated Returns* Per Acre of Three F_1 Lines and Four Varieties of Tomatoes Commonly Grown in R. I.

F_1 Line or Variety	Marketable Yields and Calculated Returns Through Aug. 12				Marketable Yields and Calculated Returns Aug 12 to Sep 29				Total Calculated Returns	
	Hillsgrove		Newport		Hillsgrove		Newport		Hillsgrove	Newport
	Bushels	Dollars	Bushels	Dollars	Bushels	Dollars	Bushels	Dollars	Dollars	Dollars
Earliana × Redcap	151	604	96	384	179	179	818	818	783	1,202
Comet	66	264	60	240	167	167	684	684	431	924
Waltham × Earliana	98	392	84	336	271	271	813	813	663	1,149
Marglobe	48	192	37	148	389	389	648	648	581	796
Valiant × Earliana	117	468	118	472	223	223	849	849	691	1,321
Bestal	35	140	46	184	359	359	872	872	499	1,056
Valiant	86	344	82	328	346	346	744	744	690	1,072

*Average of 4.00 per bushel through Aug 12; average of 1.00 per bushel from Aug 12 to Sep 29.

for the remaining yields, calculated monetary returns for the strains may be compared. Under the columns of calculated returns in Table V it may be seen that the overall returns on the two F_1 lines, Earliana x Redcap and Valiant x Earliana, were consistently greater than the returns from the better varieties.

It has been determined that hybrid seed could probably be produced for \$8.00–\$10.00 an ounce (1, 2). The calculated returns on the F_1 line Earliana x Redcap, at Hillsgrove, exceeded the better variety by \$91.00 per acre. Valiant x Earliana at Newport averaged \$249.00 per acre more than did the variety Valiant which was shown to give the greatest returns of the pure lines.

Both F_1 lines produce marketable size fruits of good color, smooth and firm. The plants are indeterminate in habit and in adverse years, such as the season this test was made, may suffer losses from blossom end rot. However, the large increase in number and weight of fruit produced per plant seems to offset this loss.

The F_1 lines were definitely earlier in maturity than the earliest variety of the test and at Newport they produced total yields as great or greater than the high yielding variety. Under irrigated conditions it is probable that similar results would have been obtained at Hillsgrove.

Summary and Conclusion

Three F_1 tomato lines and 10 inbred strains were tested on two widely varying soil types to determine the possibility of varied responses. Early yields were significantly greater on the Merrimac Fine Sandy Loam Soil (Hillsgrove). Average fruit size, total yield, and marketable yields were significantly greater on the Bernardston Loam Soil (Newport).

It was definitely shown that certain F_1 lines and strains did not respond the same to the two soil types. This is of interest since it indicates the probable necessity of breeding F_1 lines as well as varieties for a particular soil type. It appears that an F_1 of indeterminate plant type would be well suited to the Merrimac Fine Sandy Loam and, to the grower intending to service the early markets, the three F_1 lines mentioned would be of considerable value.

All three F_1 lines responded well on the Bernardston loam soil. The calculated cash returns from the F_1 lines ranged from 77 to 249 dollars more per acre than the best inbred strain.

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A Polyploid Watermelon

By P. L. Hawthorne, *North Louisiana Experiment Station, Calhoun, La.*

Since occurrence of natural polyploidy in watermelons is extremely rare in nature, this paper is presented to give the performance of such a plant found growing in a commercial field of watermelons. This plant was observed growing in a field planted to the Holmes variety. During the process of inspecting watermelon fields in the North Louisiana area to ascertain about what per cent plant mortality occurred during the first five weeks of the growing season from wilt (*Fusarium Niveum* E. F. S.), a plant was noted that was unusually vigorous. This plant possessed very large runners, broad heavy foliage, and the pollen grains and staminate and pistillate flowers were about double the size of those on plants true to variety. This plant exhibited marked resistance to the natural field infection of anthracnose (*Colletotrichum lagenarium* (Pass) Ell. & Hals.) leaf spot as compared to neighoring plants.

A wilt resistance breeding program were underway on the North Louisiana Station, so crosses were made between this anthracnose free polyploidy plant and two of our most wilt resistant stocks with the idea in mind to develop a strain highly resistant to both diseases. Four flowers were cross-pollinated and six were inbred. These pollinations resulted in three sets from the four cross pollinations and no sets from the inbred flowers. Twenty-six crosses were made by using pollen from the polyploid plant on pistillate flowers on plants of several varieties, including the parent strain. These pollinations failed to set a single watermelon. Thus conclusions were drawn that the pollen was not viable.

The three watermelons that were produced as a result of the four cross pollinations were found to be of good quality and texture and contained about two-thirds the normal amount of seed. This indicated normal pollination had taken place.

These hybrid seeds were planted the following year, but came up to a very poor stand. The plants that did survive the unseasonal weather conditions in 1943 exhibited only a portion of the vigor and anthracnose resistance of the mother plant. All thirty-eight pistillate flowers produced on the hybrid plants were inbred with very poor results. Only three watermelons matured. One melon in one inbred combination produced only two mature seeds and the two matermelons of the other inbred line contained eleven matured seeds. These seed were very carefully handled and planted in the spring of 1944. Four of the thirteen seeds planted germinated but were too weak to survive.

A Comparison of Six Tomato Varieties as Parents of F_1 Lines Resulting from the Fifteen Possible Crosses[1]

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To realize fully on the high yield and other desirable characters of tomato hybrids will require extensive testing of numerous combinations in order to identify those most promising. The large number of possible combinations is due to the numerous varieties and strains that exist. Using n as the number of parents, the formula $\frac{1}{2}n\ (n - 1)$ gives the number of crosses possible. Thus if 50 varieties were to be used the number of combinations would be $\frac{1}{2}\ 50 \times 49 = 1225$. This is a scale of work beyond feasibility and a more simple method of eliminating those varieties with poor combining ability is indicated. Sprague and Tatum (3) have distinguished between specific and general combining ability of inbred lines of corn. The former can only be determined by individual crosses but the latter may be determined for a tomato variety by averaging its performance in several combinations, preferably with varieties that are known to have good combining ability. In corn the top cross is used as a test of general combining ability. In tomatoes the crossing of the variety with a few F_1 lines as testers would appear suitable, but it seems desirable to know as much as possible regarding the general combining ability of the varieties making up the parentage of such F_1 lines.

In 1943 a test was conducted cooperatively by the Minnesota and Rhode Island Stations to study the productivity and general desirability of a number of F_1 hybrids and to compare the combining abilities of five established varieties and one unnamed selection. It is thought that this information will be of value in establishing a few varieties as tester parents, thereby providing a beginning toward testing the combining ability of numerous varieties and strains. Also it was desired to learn to what extent the phenotype of a homozygous parent might indicate its performance as a parent of hybrid lines and its value as a parent in pedigree breeding of new varieties. Eventually it is planned to summarize the records on yield, earliness, fruit size and shape and vitamin C content from the two widely separated localities. However, this presentation is limited to yield alone.

Material and Methods

Six varieties were crossed in all possible combinations. The choice of the varieties was based to some extent on date of ripening as well as general adaptability. It was desired to represent a range of ripening dates and confine the choice to well established varieties with the

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exception of one selection as yet unnamed. No distinction between reciprocal crosses was made. In two known literature references reciprocal crosses of tomato varieties have shown differences but it is unlikely that such differences actually exist. Myer and Peacock (2) and Driver (1) gave data in which reciprocal crosses seemed to differ but in neither instance was the data accompanied by variability measurements. Those instances where differences have been statistically tested show no significance between reciprocal crosses. This is also in agreement with the general genetic theory on such crosses.

The 15 crosses and six parents were grown in randomized block arrangements at St. Paul, Minnesota and Kingston, Rhode Island. Seed of the Earliana x Pritchard F_1 did not germinate at Rhode Island and was therefore not in the test at this locality.

Results

Table I presents the marketable yield figures obtained in the test at St. Paul. The data are submitted in the form of two-way tables with the selfed progenies shown as the underscored figures on the diagonal. It will be noted that the columns are duplicates of the rows with the first column being the same as the first row and so on. The means for the parental varieties in all crosses are shown in the last column of the table and furnishes a basis for comparing the general combining ability of the varieties. Earliana exceeds all parents in yields of progeny. The mean difference between it and the second highest is 1.64 ± 0.44 tons per acre. Marglobe seems the poorest in general combining ability, but compared statistically was not inferior to Pritchard and Rutgers. That specific combining ability may be of

TABLE I—Yields in Tons of Marketable Fruit Per Acre* for Six Tomato Varieties and the F_1s of All Combinations Grown at St. Paul, Minnesota, 1943

Parents	6-39	Marglobe	Rutgers	Pritchard	Earliana	Bonny Best	Total of Crosses	Mean of Crosses**
6-39	*5.73*	3.43	7.03	6.14	8.93	8.64	34.17	6.83
Marglobe	3.43	*3.69*	5.69	5.37	7.83	6.25	28.57	5.71
Rutgers	7.03	5.69	*4.05*	4.36	8.04	4.76	29.88	5.98
Pritchard	6.14	5.37	4.36	*4.20*	9.61	5.58	31.06	6.21
Earliana	8.93	7.83	8.04	9.61	*7.26*	7.92	42.33	8.47
Bonny Best	8.64	6.25	4.76	5.58	7.92	*6.59*	33.15	6.63

*Sig. Dif. 1.80.
**Sig. Dif. 0.76.

significance is shown by the cross Pritchard x Earliana which was slightly higher in yield than any cross in the test and significantly so with four exceptions. This is of interest since Pritchard showed rather poor general combining ability.

Table II contains the data obtained from the test in Rhode Island. Since no plants were obtained from the one cross the space for this data in the table is blank. In this test the best general combining ability was shown by Rutgers, but Bonny Best was not significantly lower. The highest yielding individual cross was Rutgers by Pritchard. In quantity of marketable fruit produced, this cross was signifi-

TABLE II—YIELDS IN TONS OF MARKETABLE FRUIT PER ACRE* FOR SIX TOMATO VARIETIES AND THE F_1S OF ALL COMBINATIONS GROWN AT KINGSTON, RHODE ISLAND, 1943

Parents	6-39	Marglobe	Rutgers	Pritchard	Earliana	Bonny Best	Total of Crosses	Mean of Crosses
6-39	*2.34*	9.09	10.52	5.07	6.88	8.57	40.13	8.03 ±0.619
Marglobe	9.09	*8.06*	12.47	8.96	10.26	14.81	55.59	11.12 ±0.619
Rutgers	10.52	12.47	*11.04*	16.75	12.99	11.95	64.68	12.94 ±0.619
Pritchard	5.07	8.96	16.75	*8.83*	—	15.97	46.75	11.69 ±0.693
Earliana	6.88	10.26	12.99	—	*4.81*	9.87	40.00	10.00 ±0.693
Bonny Best	8.57	14.81	11.95	15.97	9.87	*0.22*	61 17	12.23 ±0.619

*Sig. Dif. 4.06.

cantly higher than all others except Bonny Best x Pritchard and Bonny Best x Marglobe which it exceeded by 0.78 ± 2.05 and 1.94 ± 2.05 tons per acre respectively.

An outstanding feature of the results is the reaction of different crosses in the two localities. Rutgers was a poor parent in the St. Paul test but at Kingston was the best, whereas Earliana was poorest at Kingston but proved to be the best parent at St. Paul. In both localities there appears to be a close agreement between the yield of a variety and its general combining ability. This suggests that the better yielding varieties for a locality will probably produce the better yielding hybrids. An explanation for the difference in response at the two localities may be resistance to certain diseases, but many other considerations might be suggested such as soil difference, day length, rainfall etc. Obviously also it may be the result of different combinations of many environmental factors.

From the foregoing, it seems feasible that strains with good general combining ability might be used to test the value of numerous varieties as parents of hybrid combination. However, it seems evident that the same tester varieties cannot be used in widely separated regions. Rather, the choice of a tester parent should be based on the performance of its progeny in the particular locality. It is however of some interest that Pritchard was one of the parents of the best yielding hybrids at each of the locations in the present test. This may be only coincidence but it is also a suggestion that this variety may have wide adaptability as a parent of hybrids, although other varieties seem to surpass it in general combining ability at specific locations.

Considering the superiority of certain hybrids over the varieties it will be noted that the highest yielding varieties were Earliana and Rutgers with yields of 7.26 and 11.04 tons per acre at St. Paul and Kingston respectively. The highest yielding crosses were Pritchard x Earliana and Rutgers x Pritchard with yields of 9.61 and 16.75 at St. Paul and Kingston respectively. At St. Paul the hybrid exceeded the yield of the highest yielding variety by 32 per cent and at Kingston the difference was 52 per cent. In the St. Paul test the cross was superior to the variety in quality and size of fruit and was not significantly later in ripening. At Kingston the hybrid graded a distinctly higher percentage of marketable fruits than Rutgers and was not significantly later. With such superior yield performance and no

sacrifice in other desirable characters it is apparent that the hybrids would be profitable to grow commercially. At the 1943 minimum local price of $1 per bushel the additional yield at St. Paul had a calculated value of $94 per acre.

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Substances Effective for Increasing Fruit Set and Inducing Seedless Tomatoes

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Gustafson (2), in 1936, reported that several growth substances caused parthenocarpic development of ovaries and induced seedless fruit. Since that time much scientific interest in the subject has been evident and practical applications have been made. Amateurs and practical growers have been especially interested in the possibility of growing seedless tomatoes in both greenhouses and gardens.

The "plant hormone" projects at the Boyce Thompson Institute have involved many chemical compounds which are active for several different physiological responses. Some of the β-naphthoxy and substituted phenoxy and benzoic acids are particularly effective for making seedless tomatoes (3, 9, 10, 11).

A number of different methods of application are being used. Gustafson (2), Strong (7), and Howlett (5) have reported on the use of lanolin preparations applied to the excised pistil of open flowers and water solutions or emulsions applied to open flowers with an atomizer. Zimmerman and Hitchcock introduced the vapor method, and the method of spraying the entire plant or the entire cluster at one time (8, 9, 11). Mitchell (6) confirmed the effectiveness of the vapor method. More recently the aerosol method of Goodhue (1) used for insecticides has been adapted for growth substance application as a mist (4, 12). In some respects this is a modification of the vapor method but requires more of the active chemical per unit volume of greenhouse space. As with the vapor method, when liberated in a greenhouse the entire plant is exposed. By use of a special cylinder (Fig. 1 A), however, the flower clusters can be treated with the mist without allowing much of the chemical to hit the plant.

β-Naphthoxyacetic acid and some of the substituted phenoxy and benzoic acids may have pronounced formative influences, modifying leaves, flowers, and fruit. When these are applied with an atomizer slightly less than the optimum concentration should be used and care should be taken to avoid hitting the leaves and growing point of the stem with the spray. If necessary precautions are taken the most active substance can be applied without causing undue modification of leaves.

The present report is a brief summary of some of the work done at the Boyce Thompson Institute laboratories to locate effective chemicals for parthenocarpy and to improve the methods of treating plants.

Table I shows a list of substituted phenoxy acids with varying degrees of activity. Table II has a list of indole and naphthoxy compounds and substituted benzoic acids which are active for parthenocarpy.

The position of the substituted groups in the benzene ring appears to determine in part the activity of the molecule. The chlorine and bromine atoms brought about nearly equal activity. These, in general,

TABLE I. SUBSTITUTED PHENOXY ACIDS WHICH INDUCE SEEDLESS TOMATOES. THE TABLE SHOWS WHICH OF THESE ACIDS HAVE THE CAPACITY TO MODIFY LEAVES

Phenoxy Acids	Effective Range of Concentrations for Parthenocarpy in mg/l of Water	Activity or Inactivity for Modification of Leaves
Phenoxyacetic acid	Inactive	Inactive
α (Phenoxy)-propionic acid	100–200	Active
α (Phenoxy)-*n*-butyric acid	100–200	Active
o-Chlorophenoxyacetic acid	200–300	Active
α-(*o*-Chlorophenoxy)-propionic acid	25–50	Inactive
α-(*o*-Chlorophenoxy)-*n*-butyric acid	50–200	Inactive
α-(*o*-Methylphenoxy)-propionic acid	50–100	Inactive
α-(*m*-Chlorophenoxy)-propionic acid	50–200	Inactive
α-(*m*-Chlorophenoxy)-*n*-butyric acid	Active	Inactive
p-Chlorophenoxyacetic acid	50–100	Active
α-(*p*-Chlorophenoxy)-propionic acid	50–200	Inactive
α-(*p*-Chlorophenoxy)-*n*-butyric acid	50–200	Inactive
2,4-Dichlorophenoxyacetic acid	5–10	Active
α-(2,4-Dichlorophenoxy)-propionic acid	50–100	Inactive
α-(2,4-Dichlorophenoxy)-*n*-butyric acid	50–100	Inactive
2,4-Dimethylphenoxyacetic acid	300–450	Active
α-(2,4-Dimethylphenoxy)-propionic acid	300–450	Active
2,5-Dichlorophenoxyacetic acid	25–100	Inactive
α-(2,5-Dimethylphenoxy)-propionic acid	100–300	Inactive
α-(2,5-Dimethylphenoxy)-*n*-butyric acid	Active	Inactive
3,4-Dimethylphenoxyacetic acid	Active	Active
α-(3,4-Dimethylphenoxy)-propionic acid	300–500	Active
2,4,5-Trichlorophenoxyacetic acid	25–100	Inactive
α-(2,4,5-Trichlorophenoxy)-propionic acid	10–50	Inactive
α-(2,4,5-Trichlorophenoxy)-*n*-butyric acid	25–100	Inactive
2,4,5-Trimethylphenoxyacetic acid	25–100	Active
2,4,6-Trichlorophenoxyacetic acid	Active	Active
β-(2,4,6-Trichlorophenoxy)-β′-chloro diethyl ether	Active	Active

made more active molecules than methyl, nitro, and amino groups substituted in the same positions on the ring. However, *o*-methylphenoxyacetic acid was more active than the corresponding chloro-substituted acid.

The power of some of the phenoxy and benzoic acids to modify the pattern of tomato leaves is of considerable scientific interest but may be detrimental from a practical standpoint.The ideal substance would be one which would stimulate growth of the ovary without seriously affecting the rest of the plant. *o*-Chlorophenoxypropionic acid approaches that requirement though it inhibits growth if applied to the entire plant. When the optimum concentration (about 25 mg/l) is applied to only the flower cluster the rest of the plant is scarcely or not at all affected.

From a concentration standpoint, the most effective chemical known for stimulating growth of the ovary is 2,4-dichlorophenoxy-

TABLE II. COMPARATIVE ACTIVITY OF GROWTH SUBSTANCES FOR INDUCED PARTHENOCARPY

Chemical	Parthenocarpy	Modification
β-Indoleacetic acid	1000–3000*	Inactive
β-Indolebutyric acid	1000–3000	Inactive
β-Naphthoxyacetic acid	50–100	Active
β-Naphthoxypropionic acid	50–100	Active
2-Chloro-5-nitrobenzoic acid	300	Active
2-Bromo-3-nitrobenzoic acid	300	Active
2,5-Dichlorobenzoic acid	100–400	Active

*Effective concentration range, mg/l.

acetic acid. Unfortunately, however, this is one of the most effective chemicals for inhibition of growth and modification of leaves. It is difficult to spray flowers with more than 5 mg/l without affecting the rest of the plant. It can be used for practical purposes, since 5 mg/l is nearly optimum for stimulating growth of the ovary.

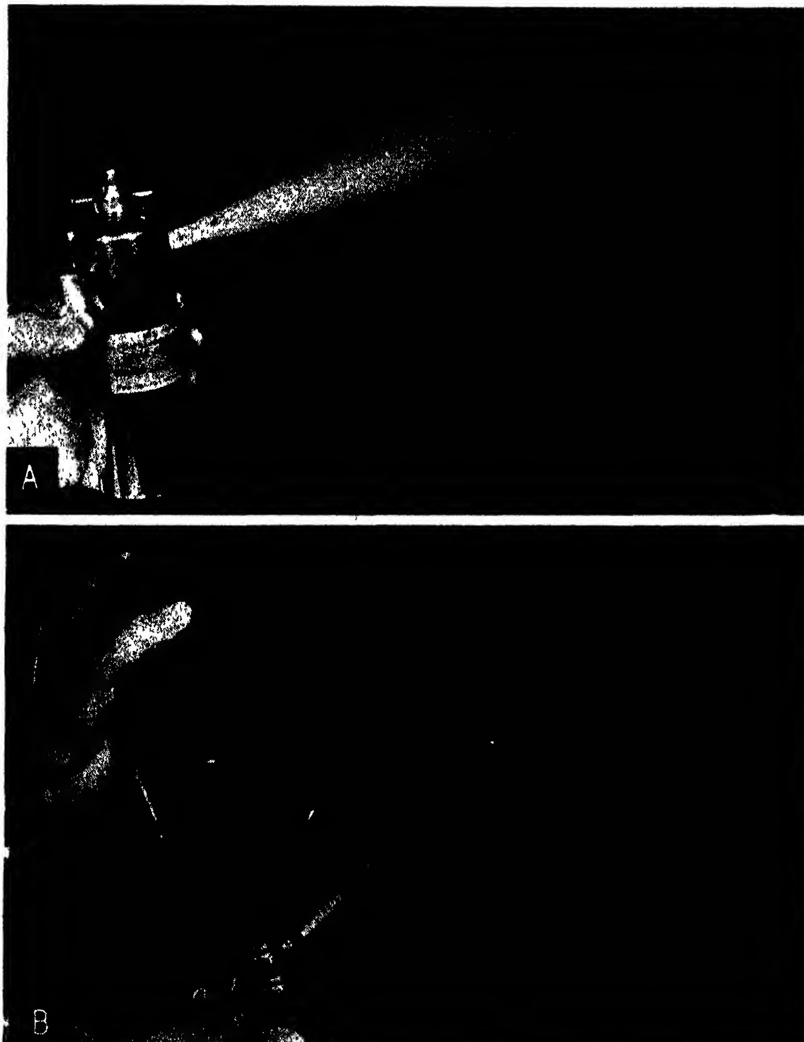

FIG. 1. Refillable cylinder dispensers used for applying aerosol growth regulators. A. Cylinder manufactured by the Milwaukee Sprayer Mfg. Co. and supplied for experimental purposes by Dow Chemical Co. B. Cylinder manufactured by the Pennsylvania Engineering Co., Philadelphia, and supplied for experimental purposes through the kindness of Mr. W. W. Rhodes of Kinetic Chemicals, Inc., Wilmington, Delaware.

2,5-Dichlorobenzoic acid is the most effective substituted benzoic acid known for stimulating parthenocarpy, but it also modifies leaves. When applied as a water solution spray, 100 to 400 mg/l are very effective for inducing seedless tomatoes. This compound is effective also when applied to the soil. One to 5 mg per 4-inch pot of soil caused fruit set of flowers and buds present when the chemical was applied to the soil. It also caused parthenocarpic development of flower buds which were initiated after the soil was treated. It may be possible to find among the benzoic acids a compound which is equally effective for parthenocarpy and which does not have such a pronounced formative influence.

TABLE III. THE RESULTS OBTAINED BY TREATING FLOWER CLUSTERS OF TOMATO (VARIETY, GLOBE STRAIN A) WITH SOLUTIONS OF VARIOUS ACTIVE CHEMICALS. THE SOLUTIONS WERE APPLIED BY MEANS OF A NASAL ATOMIZER. THE CLUSTERS WERE THE FIRST AND SECOND SETS PRODUCED BY THE PLANTS

Chemical	Conc. mg/l	Condition of Flowers When Treated				Total Number of Flowers and Buds Treated	Total Number of Fruit Set	Per Cent of Fruit Set
		Old	Open	Color	Bud			
o-CPOP*. . .	25	0	7	3	6	16	16	100
o-CPOP. .	50	2	14	5	13	34	28	82
o-CPOP.	100	2	9	4	6	21	16	76
2,4-CPOA** .	5	1	12	4	6	23	21	91
2,4-CPOA . . .	10	1	8	5	12	26	25	96
2,4-CPOA. . . .	20	0	11	4	3	18	17	95
KIB† . .	3000	0	2	1	2	5	3	60
Control . .	Pollinated	4	7	7	8	26	21	81

*o-CPOP = ortho-Chlorophenoxypropionic acid.
**2,4-CPOA = 2,4-Dichlorophenoxyacetic acid.
†KIB = Potassium Indolebutyrate.

Results which can be had by use of the spray method are illustrated in Tables III and IV where only one application of the spray was made to a cluster. Control clusters were pollinated by hand repeatedly when flowers were open. Table V shows results obtained by the aerosol method involving a cylinder for dispensing a mixture of Freon, growth substance, and sesame oil. The mist, formed when the valve

TABLE IV. THE RESULTS OBTAINED BY TREATING FLOWER CLUSTERS OF TOMATO (VARIETY, BONNY BEST) WITH SOLUTIONS OF VARIOUS ACTIVE CHEMICALS. THE SOLUTIONS WERE APPLIED BY MEANS OF A NASAL ATOMIZER. THE CLUSTERS WERE THE FIRST AND SECOND SETS PRODUCED BY THE PLANTS

Chemical	Conc. mg/l	Condition of Flowers When Treated				Total Number of Flowers and Buds Treated	Total Number of Fruit Set	Per Cent of Fruit Set
		Old	Open	Color	Bud			
$2,5\text{-}Cl_2B$*.	100	1	14	4	16	35	32	92
$2,5\text{-}Cl_2B$	200	2	11	8	10	31	22	71
$2,5\text{-}Cl_2B$. . .	300	2	18	10	18	48	39	81
$2,5\text{-}Cl_2B$. . . .	400	5	12	7	13	37	31	84
$2,4\text{-}Cl_2POA$**	10	3	11	10	10	34	27	79
Control.	Pollinated	5	18	7	20	50	40	80

*$2,5\text{-}Cl_2B$ = 2,5-Dichlorobenzoic acid.
**$2,4\text{-}Cl_2POA$ = 2,4-Dichlorophenoxyacetic acid.

TABLE V. The Results Obtained by Treating Tomato (Variety, Bonny Best) Plants While in Flower with *o*-Chlorophenoxypropionic Acid Ethyl Ester by the Aerosol Method. The Cylinder Used in the Operation Contained Two Pounds of Freon, 500 mg of the Growth Substance Dissolved in 25 cc of Acetone, and 3 cc of Sesame Oil. When Released from the Cylinder a Mist Was Formed

Treatment	Condition of Clusters When Treated				Total Number of Flowers and Buds	Total Number of Fruit Set	Per Cent Set
	Old	Open	Color	Buds			
Aerosol *o*-CLPOPEE 100 mg in 2,500 cubic feet greenhouse	3	14	6	13	36	28	78
Vapor 50 mg of *o*-CLPOPEE in 2,500 cubic feet volume	0	9	1	9	19	13	69
Aerosol (*o*-CLPOPEE) mist directly on the flower cluster	3	6	2	10	21	14	67
Controls not pollinated	2	7	2	9	20	0	0

was opened, remained suspended in the air for several hours while the ventilators were closed.

Fig. 2 A shows fruit set with 2,5-dichlorobenzoic acid. The solution (300 mg/l) was applied once only with an atomizer to the back side of the flower cluster when three flowers were open but past their most receptive stage. Three buds were very small. The next larger buds had ovaries developing when the cluster was removed. They may or may not have developed to full size had they not been removed.

Fig. 2 B shows a pollinated control and fruit set induced with 2, 4-dichlorophenoxyacetic acid — the most effective substance from a concentration standpoint. The tomato variety is a special strain of Globe supplied by Dr. F. S. Howlett of the Ohio Agricultural Experiment Station. The chemically-treated fruit grew much faster than the controls. Where 5 mg/l were used and only one treatment given, the small buds also developed parthenocarpically. Buds frequently showed considerable development of the ovaries long before the petals opened. The cluster on the right in Fig. 2 B shows inhibition of buds and some splitting of the fruit due to the use of higher than the optimum concentration of the chemical. One fruit shows the gelatinous pulp with ovules but no seeds. This peculiarity occurred more frequently with Globe than with the Bonny Best variety. In general, it appeared that the Globe variety was more sensitive to the growth substances than either Marglobe or Bonny Best varieties.

Fig. 3 A shows a non-pollinated control cluster of Bonny Best tomatoes and a cluster three days after exposure to aerosol in a greenhouse of 2,500 cubic foot capacity. Approximately 450 mg of ethyl 2-chlorophenoxypropionate were liberated as a mist from a cylinder containing the following mixture: 1.1 pound Freon, 50 cc acetone, 1 gm ethyl 2-chlorophenoxypropionate, and 3 cc of sesame oil. With this mixture the internal pressure due to Freon was approximately 150 pounds. The ester and sesame oil were dissolved in the acetone and placed in the cylinder before it was filled with Freon. The cylinder (Fig. 1 B) was a 2-pound capacity refillable dispenser supplied for

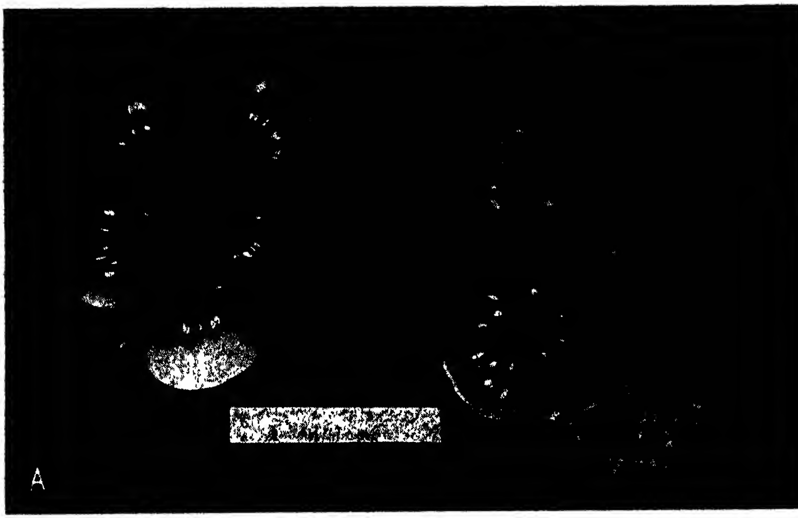

FIG. 2. Chemically induced parthenocarpy of tomatoes. A. Bonny Best variety. Left, pollinated control, photographed 39 days from first open flower. Right, solution of 2,5-dichlorobenzoic acid (300 mg/l) applied with an atomizer when 3 flowers were open, photographed 31 days later. B. Globe strain A variety. Left, pollinated control. Middle, sprayed with solution of 2,4-dichlorophenoxyacetic acid (5 mg/l) when 3 flowers were open. Right, sprayed with 2,4-dichlorophenoxyacetic acid (20 mg/l) when 3 flowers were open. Photographed after 25 days.

experimental purposes by the Pennsylvania Engineering Co., Philadelphia, Pennsylvania.

Fig. 3 B shows an unpollinated control cluster and an experimental cluster five days after being treated directly with aerosol growth substance from a dispenser shown in Fig. 1 A. The mixture in the dispenser was as follows: α-(2-chlorophenoxy)-propionic acid 0.10 gm, sesame oil 2.0 gm, and Freon 100.0 gm.

At the time the representative cluster shown in the picture was

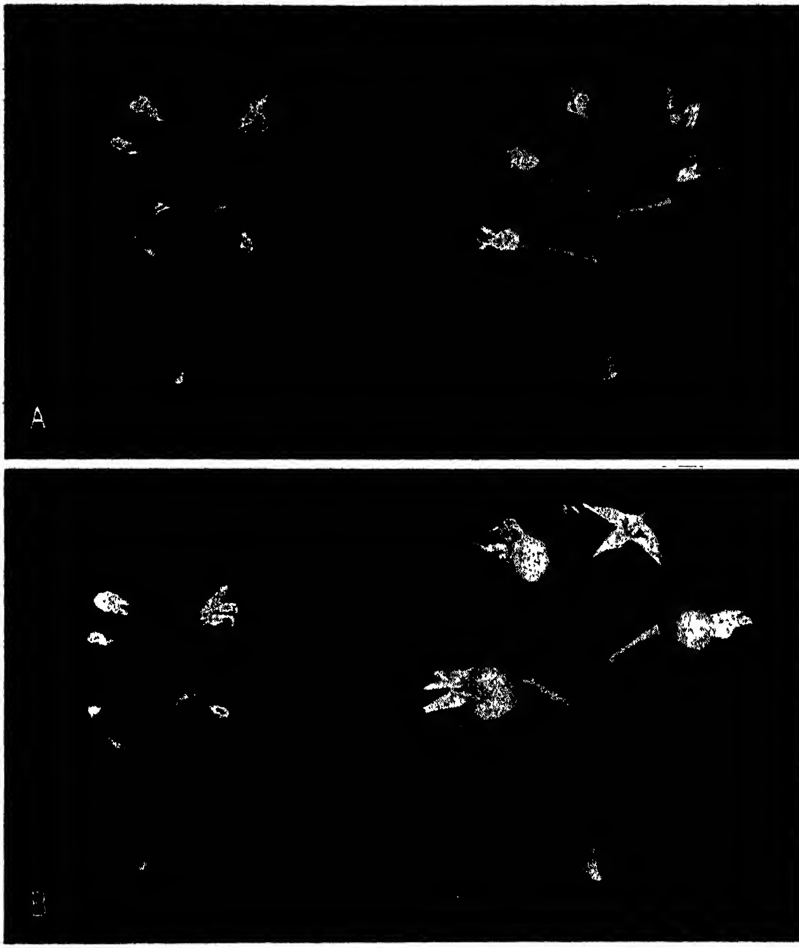

FIG. 3. Tomato, Bonny Best variety. A. Left, control, not pollinated. Right, cluster three days after exposure to aerosol dispensed from cylinder shown in Fig. 1 B. A total of 450 mg of ethyl α-(2-chlorophenoxy)-propionate were liberated in a greenhouse of 2,500 cubic feet capacity. At the beginning the cluster had 1 old flower, 3 open, and 1 bud with color. B. Left, control. Right, cluster 5 days after being treated directly with mist from cylinder shown in Fig. 1 A. Cylinder contained α-(2-chlorophenoxy)-propionic acid 0.10 gm, sesame oil 2.00 gm, and Freon 100.00 gm. When treated, cluster had 3 open flowers.

treated there were three open flowers and two buds not showing color. The fact that flowers opened after the cluster was treated with aerosol growth substance indicated that growth was not unduly inhibited by the chemical. The stimulated ovaries grew rapidly and pushed the petals to one side where they remained for days or weeks without withering. This is a characteristic response and is an indication of

high physiological activity. The corollas of control flowers withered within a day or two after pollination was effected.

Attempts to grow seedless tomatoes in the garden during the summer of 1943 were reasonably successful. The chemical treatment was especially effective to set fruit on the first clusters during the cold, wet days when natural fruit set was very poor. For garden work 2-chlorophenoxypropionic acid (25 to 50 mg/l without a spreader) and 2, 4-dichlorophenoxyacetic acid (5 to 10 mg/l without a spreader) applied as a spray with an atomizer were effective. During the warmer part of the growing season when insect pollination was ample, it was difficult to obtain complete seedlessness of tomato fruit. Partially seedless fruit were easy to produce, and there was an indication that the fruit from treated clusters were larger than controls. There was practically no difference in the total crop of control and experimental plants.

While all the chemicals listed in Tables I and II can be successfully used for inducing seedless tomatoes, four of these substances, 2-chlorophenoxypropionic acid, 2,4-dichlorophenoxyacetic acid, 2,5-dichlorobenzoic acid, and β-naphthoxyacetic acid, are particularly effective. All of these can be applied as a water solution without a spreader. The substituted phenoxy acids are very stable and have been kept as prepared solutions throughout the summer without losing their effectiveness.

The minimum effective concentration for each tomato variety should be determined and the minimum effective concentration should be used in preference to higher dosages. While there is sure to be an effective range, the higher concentrations cause inhibition of growth, modification of shape, and loss of the smaller buds.

Methods of application can be varied to meet the peculiar needs of the experimenter or grower. For the inexperienced growers and scientists who work with only a few plants, water solutions applied with an atomizer are to be recommended. The spray should be applied to the peduncles, to the back of the buds and flowers, and to the open side of flowers. It is a fact, however, that a single application of the spray to either back or open side of the flower will induce a high fruit set.

The aerosol method which is a variation of the spray methods may come to be important. The dispenser shown in Fig. 1 A is more convenient than an atomizer for treating individual clusters of flowers. Also as indicated from a limited number of tests, the aerosol growth substance dispensed in this way appeared to be more effective than a water solution. An entire greenhouse, of 10,000 cubic foot capacity, full of plants can be treated at one time by dispensing aerosol growth substance from a cylinder holding only 2 pounds of Freon. The objection may be made that by this method not only the flowers but the whole plant is exposed to the active chemical. There are, however, some compounds active for parthenocarpy which do not greatly inhibit growth of the plant. When still better growth substances are available, the aerosol method will become more and more important.

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Fixation of Cabbage Varieties

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Considerable difficulty may be encountered by commercial seed growers in fixing variety characteristics of cabbage. Some of this can be traced to one or more of the following causes: (a) Expression of cabbage characters frequently depends on variable factor complexes. (b) Cabbage plants frequently depend on cross-pollination for vigor and for perpetuation of their kind. (c) Progeny of even self-pollinated flowers seldom, if ever, are perfect duplicates of their immediate parents because of their hereditary factor complexes. (d) Ideals of the plant breeder, for various reasons, may not be achievable. Chief among these reasons are the many factor complexes involved, also often there are limitations in the necessary plant materials. The last cause can be eliminated by use of a procedure outlined in this paper.

That some of the older varieties were quite heterogenous in plant characters is well known. Detjen (1) isolated many distinct strains, such as, annual, non-heading, rosette, asparagodes, compatible and non-compatible, pigmented and non-pigmented, all from one variety (Volga or Stone).

With self-compatibility established, varieties may be readily purified through selection. Any loss in plant vigor may be reestablished by proper crossing of siblings bearing similar genetic and somatic characters. With self-incompatibility prevailing, the purifying process is not so simple. Pearson (5) has shown that, by pollinating in the bud about 2 days prior to anthesis, cross-incompatibility in cabbage-like plants can be circumvented and normal selection can be used to quickly reduce any mixed group of plants.

In order to produce hybrid seed, Pearson (5, 6) suggests the crossing of two lines of self-incompatible, cross-compatible plants, which have been previously purified through bud pollination and selection. In either instance the characteristics of the parental lines must be maintained at such high level of purity that their progenies, in order to conform to the required standards of a variety, display at least a certain degree of uniformity. To keep the parental lines pure in composition and unwavering in character is a serious problem that confronts every seed grower.

Because of the great number and complexity of factors that are involved in the fixation and maintenance of cabbage characters, a modification in the routine procedure used in seed production is proposed by which the type or variety once achieved can be permanently fixed or frozen.

After desirable self-compatible plants or lines have been obtained, it is suggested that vegetative propagation of seed-plant materials be used to perpetuate, without change of characters, the original seed-

producing plant types. The self-compatible group will require but one desirable plant to become the progenitor of that type of clone while self-incompatible groups will, of necessity, require selected pairs.

Seed-plant material, chosen in the fall, can be propagated in the following three ways:

1. Vegetative propagation by means of healthy vigorous leaves as described by Isbell (3).

2. Vegetative propagation by means of slips; i. e., lateral slips from stem buds as practiced by Lindly (1831) and Kendall (1833) and reported by Isbell (3).

3. Vegetative propagation by means of offset-like growths produced on seed branches of cabbage plants, which either by nature or by artifice, are more vegetative than reproductive in character during their normal seeding year.

The third and last method was the one often used by Detjen (1) early in the 1920's to perpetuate self-unfruitful plants. This method will be described in detail.

The routine suggested for the handling of cabbage plants to be used for commercial seed production is as follows:

The plants, after removal from storage, are planted in a glass house for the initiation of flowerstalks which are to serve as framework for the production of vegetative shoots. When flowerstalks have developed sufficiently, the house temperature is raised either artificially or in the more southern climates this may naturally occur by the gradually rising outdoor temperatures of late winter and early spring. The rising temperatures, according to Miller (4), will effect a change in the nature of the plant growth. Reproductive trends will be reversed to those of vegetative growth (Fig. 1). If the plants are robust, larger numbers of vegetative shoots can be expected. When of sufficient size, these offset-like shoots should be detached, rooted in clean sand, and potted in rich soil for early summer field planting (Fig. 2).

FIG. 1. Cabbage seed plant forced back from a reproductive to a vegetative condition. All strong vegetative tips can be removed and rooted in sand.

FIG. 2. Cabbage plants ready to be set into the field. The four potted plants (foreground) are rooted vegetative offsets from seed plants. The flat contains normal cabbage seedlings.

FIG. 3. Cabbage plants propagated vegetatively from a single seed plant. Note uniformity in plant type.

During the summer months, the plants in the field are handled like any other late cabbage and, normally, by fall they will have developed heads.

Theoretically these should be exactly alike (Fig. 3) and should mature evenly. In actual practice it was observed that there may be a considerable variation in time of heading. The reason for this may be found either in changes of the environment or in vegetative material variability as found by Detjen (2) when the slips are taken from various levels on the parent plant.

At the end of the growing season, the plants are lifted by groups and stored for their necessary rest periods. After from 4 to 6 weeks of storage, some of the plants are transferred to the greenhouse for vegetative propagation similar to that of the preceding season. The vegetative propagation takes care of the multiplication and perpetuation of desirable plants or strains. The remaining stored plants or those not needed for vegetative propagation are left in storage for the winter. In late winter or early spring these are removed and set into the field for seed production (Fig. 4).

Should the original vegetative mother plant be fully self-compatible, then all of these field planted individuals will be not only self-compatible but cross-compatible with all of those within the group because of their

clonal relationship. Plants derived from cross-pollination within such a group cannot differ from similar plants derived from self-pollination because of the nature and origin of the seed plants.

All self-compatible clones to be used for seed production must be isolated from one another because of the constant danger of intercrossing. Clones of the self-incompatible kind must be planted, either in pairs or in mixed lots. As the product of the direct cross is not essentially different from that of the reciprocal cross, seeds from all plants are saved and sold as hybrid seed.

FIG. 4. Self-compatible cabbage plants propagated from a selected seed plant grown and fruited *en masse* without fear of contamination. Cross-pollinated plants within the group are only self-pollinated due to their clonal relationship.

In this fashion any variety can be fixed for as long as seed plants can be propagated vegetatively.

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Effect of Hormone Dust on Pod-set and Yield in Beans[1]

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Growers of dry edible beans commonly suffer losses in yield in seasons when temperatures are abnormally high during the period of blossoming and pod-setting. This may be due to "blasting" of the blossoms or to the formation of an abscission layer causing the flower-buds to drop before anthesis, or both. Any treatment or cultural practice which would prevent this defection would be of significant economic benefit.

Recently, a number of experiments in which growth promoting substances applied either as sprays or dusts to increase pod-set and yield of beans have been reported. The results of these experiments generally have been variable and inconclusive. Allen and Fisher (1) at the Wisconsin Station applied Parmone and App-L-Set, both containing naphthaleneacetic acid in dust and in spray form, to wax and greenpod snap beans to prevent blossom drop. The yield of wax beans was increased 464 pounds to the acre while with the Refugee variety there was no benefit. Dust application gave better results than spray. Dexter (2) at the Michigan Station applied 13 different kinds of "standard commercial mixtures available to the public" to pea beans. Eight mixtures were applied as dust to the seed and five other mixtures as plant sprays. In no case were the results beneficial and in no case were the differences significant. There was some indication that dusted seed was retarded in germination. Kiesselbach (3) at the Nebraska Station used five synthetic and two commercial hormone dusts on seed of oats, barley, soybeans, and corn. These included levulinic acid, indoleacetic acid, indolebutyric acid, phenylacetic acid, naphthaleneacetic acid, Grain 0 and Staymone. There were no beneficial effects on any of the four crops. The higher concentrations of naphthaleneacetic acid treatments were toxic and harmful to germination, growth and yield. Murneek, Wittwer and Hemphill (4) recently reported results of spraying snap beans with two growth promoting substances, naphthaleneacetamide and naphthoxyacetic acid at various concentrations. These hormones had been shown to stimulate fruit production in tomatoes. Using the Stringless Greenpod variety, these materials were applied on a field scale every few days from budset to late harvest during the years 1941, 1942 and 1943. In the hot season of 1941, the authors state that the treated plants produced more pods and a yield increase of 59 to 72 per cent, most of the increase resulting from an increased set of pods rather than from an increase in size of pods. In 1942, a cool season, the results in terms of both pod-set and yield were negative. In 1943 a moderately warm, rainy season, the treatments resulted in earlier ripening, an increase in chlorophyll content of the leaves, and an increase in yield. These authors concluded that hormone sprays are most likely to be beneficial in hot seasons and may result negatively in cool seasons.

[1]Paper No. 266 of the Department of Vegetable Crops, Cornell University, Ithaca, New York.

Experiment I

A commercial hormone sold as Rootone was used to treat the dry seed of the Rainy River variety of pea beans. Treatment consisted of thoroughly dusting the seed at the rate of 1 teaspoonful to the pound. The seed was planted on June 26 in four replications of 30-foot blocks, the treated and untreated seed being alternated in adjacent rows for paired comparison. No consistent difference in time of emergence or growth of the plants could be observed at any time. The yield results analyzed by the method of Student are shown in Table I. Although the stand of plants was excellent, the yields were exceptionally low. The rainfall during July and August was only slightly below normal but it was poorly distributed and the temperature during the blossoming period was abnormally high. Odds of 3.4 to 1 indicate that the small difference in yield in favor of the treated seed was not significant.

TABLE I—Rootone Dust Treatment of Pea Bean Seed. (1943)

Block	Bushels Per Acre		
	Treated	Untreated	Difference
A	8 2	7.5	0.7
B	12.7	10.0	2.7
C	9.8	11.1	-1.3
D	8.1	7.3	0.8
Mean	9.7	9.0	0.7
Odds of Significance			3.4 to 1

Experiment II

A much more elaborate experiment was designed to test the effect of hormone dust applied to bean plants during the blossom period. The commercial hormone sold as Parmone was applied with hand dusters in a concentration of 70 to 140 parts per million of naphthaleneacetic acid and at the approximate rate of 8 ounces per 100 feet of row. Twenty-nine types, varieties and seed sources of field beans, including pea, medium, marrow, red kidney and white kidney varieties, constituted the plant material. The experiment was planted on June 21, all 29 lots of seed being in each of four replications or blocks and arranged in series to absorb any variation in soil. The rows in each block were 30 feet long and 36 inches apart. The pea and medium varieties were seeded four to the foot, the marrows and kidneys six to the lineal foot of row.

Dust applications were made on July 31, August 7 and August 14 to cover the full period of blossom development. The July application was made when the lower blossoms were fully developed, the upper ones at the bud stage in most varieties. Observations indicated that the yelloweyes and marrows blossomed over a shorter period than the kidneys, the pea and medium varieties over a much longer period.

Since the results noted by previous investigators indicate the importance of temperature influence, special note is made of this factor. Weather observations were recorded at a station within a

mile of these plots. The maximum temperatures on the dates of dust application were 85, 76 and 86 degrees F respectively. During the period July 31 to August 14 inclusive, the mean maximum temperature was 83.1 degrees, that for the entire month of August 79.5 degrees. This means that the temperature maxima during the blossoming period averaged 4.1 degrees above the normal for August at the Ithaca station; 10 of the 15 days being warmer than 80 degrees.

Results

To measure the effect of the hormone dust on set of pods, the number of pods was recorded for each plant as it was pulled at harvest time. For yield of dry-shell beans, the crop from each 30-foot row was threshed, recleaned and weighed in grams, the latter being converted to bushels per acre. Inasmuch as different types of beans blossoming and maturing at different times might be differentially effected, the five distinct types are separately compared as shown in Table II.

TABLE II—Parmone Dusting of Field Bean Plants. (1943)

Varietal Type	No. of Strains and Varieties	Ave Number Pods per Plant				Ave Yield per Acre (Bushels)			
		Treated	Not Treated	Difference	Odds	Treated	Not Treated	Difference	Odds*
Pea	4	12.45	13.68	1 23	19:1	12 6	13.3	0.7	n.s.
Medium	2	8.64	9.99	1.35	171:1	13.3	13.4	0.1	n.s.
Marrow	7	4.79	5 73	0.94	311·1	13.7	15.7	2.0	n.s.
Red Kidney	5	4.21	4.95	0.74	3333:1	15.4	17.5	2.1	n.s.
White Kidney	11	3.82	4.56	0.74	4999·1	14.4	16 1	1.7	23:1
Total and average	29	5.64	6.54	0.90	9999:1	14.1	15 7	1.6	n.s.

*n.s. means not significant.

Discussion

In this experiment the four 30 foot blocks or replications were arranged end to end, the first and third blocks being dusted, the second and fourth blocks untreated. In analyzing the results it was, therefore, feasible to compare each treated replicate with its adjacent control replicate making a total of 58 paired comparisons.

Pod-set:—The average number of pods per plant was significantly reduced by the dust treatment in all five types, the reduction being greatest in the types typically bearing the highest number of pods. In only 12 instances or 21 per cent of the 58 paired comparisons was the pod-set higher in the treated than in the untreated plants. The average difference in set of pods was only 0.9 of a pod but this difference, according to Student's method of analysis, is highly significant. It is suggested that the reduction in set of pods caused by the hormone treatment was due to toxicity which interfered with anthesis.

Yield:—On the basis of averages, the dust treatment reduced the yield of dry shell beans in each of the five types, the average reduction for the 29 lots being 1.6 bushels to the acre or about 10 per cent. However, this difference is not statistically significant. In 36 instances

or 62 per cent of the paired comparisons, the dusted plants exceeded the untreated lots in yield. The only type of beans in which the treatment significantly reduced the yield was white kidney where the difference was 1.7 bushels to the acre with odds of 23 to 1.

Conclusions

Dusting of seed beans under the conditions outlined in Experiment I did not result beneficially. Rootone, a root-growth promoting substance, used in this instance may have been dissipated under relatively dry seedbed conditions before it could affect the seedling plants. The application of Parmone as a dust containing naphthaleneacetic acid in three applications at 1-week intervals during the blossoming period significantly reduced the set of pods. This may be ascribed to a toxic effect which interfered with normal anthesis of the flowers and which resulted from an excessive concentration of the hormone. Although the dust treatment also reduced the yield of dry-shell beans, the reduction was not significant except in white kidney. This is explained on the basis that seasonal conditions were unfavorable for a normal yield as none of the types yielded well regardless of treatment. It is probable under these conditions that, as the hormone dust reduced the set of pods, these pods "filled" better than those on the untreated plants.

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Supplementary "Hormone" Sprays for Greenhouse-Grown Tomatoes[1]

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When tomatoes are grown in greenhouses, it is difficult to obtain a desirable set of fruit under certain environmental conditions, especially subnormal light of winter and early spring months. A satisfactory remedy not having been found, attention has been centered lately on the use of so-called "growth substances" or plant "hormones", since it was demonstrated by Gustafson (1) that they can induce fruit development (parthenocarpically). A large number of effective substances for this purpose has been discovered now and new ones are being added rapidly (10, 11). Convenient methods of application are being devised and "hormone treatment" is entering the "practical phase" of development. In the form of sprays or fumigants they are now used largely supplementary to pollination and seed formation under conditions when this is a limiting factor in fruit setting and development.

Our investigations in this field were begun in the fall of 1941 and have been continued more or less uninterruptedly since and on an increasing scale.

The 1941–1942 Experiments

A commercial strain of Marglobe tomato plants were grown for these experiments. They were raised as per acceptable greenhouse practice but grown in 4-gallon containers for reasons which need not be elaborated here. A sterilized good potting soil is used by us for such cultures. It is enriched with 4–16–4 fertilizer and additional organic matter and readily available N-fertilizer ($NaNO_3$) is supplied when needed as a top dressing. Under such procedure very vigorous plants are usually obtained. They are trained to a single stem.[2] In the present experiment there were 14 plants, in duplicate, for each of the treatments.

Spraying with two growth substances, α-naphthalene acetamide (NA) alone and combined with β-naphthoxyacetic acid (NOA), at concentrations of 20 parts per million (ppm), was begun on November 15, when the first flowers were opening, and continued, at weekly intervals, for 3 months. The chemicals were dissolved in ethyl alcohol, diluted with tap water and applied by means of a barrow hand pump sprayer to the whole plant. *In this and all other experiments the open flowers were hand pollinated once or twice, by tapping the peduncles and/or pedicels vigorously and repeatedly with a pencil, before the growth substances were applied.* This was thought desirable to assure at least some pollination and seed formation previous to the treatment. More or less cloudy weather prevailed during the winter months.

[1]Missouri College of Agricultural Journal Series No. 963.

[2]The same variety and described method of growing the plants were used in all subsequent experiments, excepting that the stems were cut below the sixth cluster of flowers in the following years.

The records presented in Table I show that as a result of this treatment the yield of mature fruit was increased appreciably. This was due to better fruit setting (more fruit per plant), especially from naphthalene acetamide, and to a larger and more uniform size, particularly from the combination of the two materials used. (Fig. 1) Moreover, the first ripe fruit were harvested about 1 week earlier from plants sprayed with NA and almost 2 weeks earlier from plants receiving the NA + NOA spray than from controls. The quality of tomatoes from the treated plants was as good, if not better, than from untreated ones. The foliage appeared somewhat greener as a result of the "hormone" application. This effect is even more marked in the case of peppers and beans, used in parallel experiments (7).

TABLE I—EFFECTS OF α-NAPHTHALENE ACETAMIDE (NA) AND β-NAPHTHOXYACETIC ACID (NOA) ON YIELD AND SIZE OF TOMATOES. WINTER CROP, NOVEMBER 15 (SPRAYING BEGUN) — FEBRUARY 14 (LAST PICK), 1941–'42. AVE. PER 10 PLANTS

Treatment (Whole Plant Sprayed)	No. of Fruit Harvested	Increase Due to Treatment (Per Cent)	Total Wt of Fruit (Gms)	Increase Due to Treatment (Per Cent)	Ave Weight of Fruit (Gms)	Increase Due to Treatment (Per Cent)
Tap water (Controls) . . .	117	—	12,213	—	104	—
NA 20 ppm*.	165	+41.0	18,072	+48.0	109	+ 4.8
NA 10+NOA 10 ppm	134	+14.5	17,208	+40.9	128	+23.1

*Ppm = parts per million in spray water.

THE 1942–1943 EXPERIMENTS

Winter and late spring crops were grown as described above. The flowers were reduced to the first four per cluster. Two days after hand pollination, growth substances were applied in the form of a lanolin emulsion to individual blossoms or clusters by means of a small atomizer, as described by Howlett (4). Special attention was paid to Indolebutyric acid (IB) but NA and NOA were also used, all at concentrations of .3 and .5 per cent.

Because of good pollination and protracted clear weather, fruit production on every plant was good, almost all flowers setting and developing large tomatoes on the first three to four clusters. Subsequently formed flowers higher up on the plants set less, showed various degrees of inhibition as a result of the subtending fruit (6). This, of course, cannot be overcome by "hormone" sprays (4, 8). The differences between the sprayed and not sprayed plants, under the above treatment, as regards number of fruit set and their size, were small and within the limits of experimental error. No records, therefore, are given here. Blossom-end rot was a disturbing factor.

While the weather was "too good" for a satisfactory test of this method of spraying, it was quite evident that an emulsion of this type was somewhat difficult to handle, in fact it was "messy" and of doubtful practical value. Then, too, the detailed procedure of reducing the number of flowers per cluster and spraying each individually seems to be unnecessary as subsequent experiments have shown. Moreover,

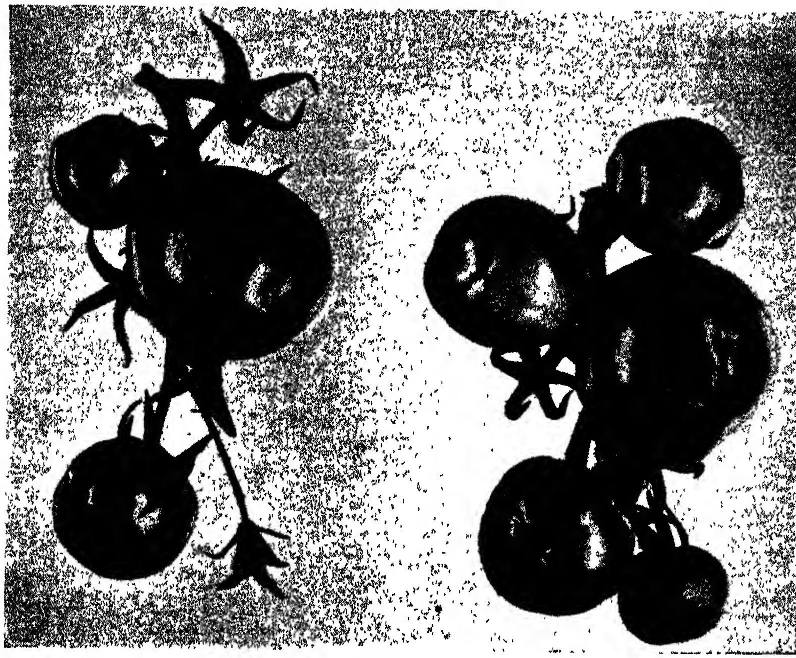

FIG. 1. Relative setting and fruit development on the first cluster of tomatoes, var. Marglobe, grown in greenhouse during cloudy weather. (Left) On control plants. (Right) On plants sprayed with β-Naphthoxyacetic acid (NOA), 20 ppm, or flower clusters sprayed with NOA, 50 ppm.

one or more of the emulsifying agents appear to have a growth stimulating effect, which complicates matters.

The 1943–1944 Experiments

Having had a fling at emulsions, we returned to water solutions of growth substances. To the ones used previously there were added the recently discovered extremely effective chlorophenoxyacetic acids (10).

A winter crop of 80 plants, grown and treated as previously described, was sprayed with aqueous solutions of four chemicals as specified in Table II. They were dissolved in dioxane, diluted as required with water and the whole plant sprayed once a week, excepting when *p*-chlorophenoxyacetic acid was used, which was applied at the same frequency to flower clusters only. Preliminary tests had shown that at this concentration (10 ppm), when sprayed also on the stems and leaves, it had a strong morphogenetic effect on meristematic tissues resulting in elongation of internodes, formation of fern-like leaves and abnormal growth of pericarps.

The weather was quite cloudy and unfavorable to fruit setting during the period of treatment. After the first 5 weeks of spraying it was observed that plants in all groups receiving "hormone" sprays were

somewhat taller and slightly darker green. Measurements taken 10 days later showed a difference of 5 to 20 per cent in height (Table II). A few weeks later this was not so obvious due to a greater inhibition in vegetative growth by the comparatively larger crop of fruit on the treated than the control plants (6). Counts of fruit set on the basal, the first three, and on all five clusters are given in Table II. It will be noted that an appreciable, though variable, increase in fruit production was obtained from all growth substances used, with some sooner and others later, but averaging 20 to 30 per cent. The first ripe fruit, fully 2 weeks ahead of those from controls, were harvested from plants receiving NA sprays, followed by NA + NOA and other treatments.

TABLE II—Effects of Four Synthetic Growth Substances on Fruit Set and Vegetative Growth of Plants. Winter Crop, 1943–'44

Treatment (Whole Plant Sprayed)	Flowers Setting Fruit (Per Cent)			Height of Plants (Cm) Days After Spraying Begun:	
	First Clusters	First Three Clusters	All Five Clusters	45	63
Tap water (Controls)	77	65	55	104	124
NA 20*.	90	83	76	123	131
NOA 20 . .	83	64	56	111	121
NA 10+NOA 10 . .	89	73	64	121	133
IB 20	75	77	74	109	127
ClPA 10 (Flower clusters only sprayed)	84	68	65	100	113

*Figures refer to parts per million of chemical used.

The results, giving the final number of fruit picked, their total and average weights are presented in Table III. It shows a conspicuous increase in number of fruit, mostly small, as a result of use of indolebutyric acid (IB). All other growth substances increased the total yield by 32 to 79 per cent. This was due primarily to an augmented and less variable size, especially so when NOA_{20} ppm and $ClPA_{10}$ ppm were used. In these particular groups, the larger the fruit the greater the number that were "puffy", with placental tissue not quite as extensively developed as that of the pericarp. None of them, how-

TABLE III—Effects of Four Synthetic Growth Substances on Yield and Size of Tomatoes. Winter Crop, 1943–'44. December 11 (Spraying Begun) — April 1 (Last Pick). Ave. per 10 Plants

Treatment (Whole Plant Sprayed)	No. of Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Total Wt of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)	Ave Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent
Tap Water (Controls) . . .	119	—	10,760	—	90.5	—
NA 20*. .	123	+ 3.3	14,290	+32.8	116.2	+28.4
NOA 20. . .	123	+ 3.3	17,950	+66.9	145.9	+60.8
NA 10+NOA 10.	117	− 1.7	15,310	+42.4	130.0	+43.6
IB 20** . . .	159	+33.6	13,980	+29.9	87.9	− 2.9
ClPA 10 (Flower clusters only sprayed) . . .	126	+ 5.9	19,320	+79.7	153.3	+69.4

*Figures refer to parts per million of chemical used.
**A proportionally large number of small fruit.

ever, were considered unmarketable. Either partial or complete seedlessness of these tomatoes was a conspicuous feature of this winter crop.

Chlorophenoxyacetic acid (ClPA) spray having given the best results in the preceding winter, a spring crop (Feb.-May) was submitted to experimental treatment with this and the closely related even more potent 2,4-dichlorophenoxyacetic acid (Cl_2PA). It was thought desirable to determine the effects of whole plant spraying with a rather weak solution of 5 and 2½ ppm of the respective substances, alone and with the addition of NOA at 10 ppm.

Within 2 weeks, after two applications of the sprays, there was a distinctly abnormal behavior of meristems of plants receiving Cl_2PA sprays, at so low concentrations, and to a slight extent also when ClPA was applied, resulting in marked elongation of internodes and conspicuous modification of other newly formed leaves. (Fig. 2)

FIG. 2. (Right) Morphogenetic effects on meristems of tomato plant sprayed with 2,4-Dichlorophenoxyacetic acid at 2½ ppm resulting in elongated internodes and fern-like leaves. (Left) Control plant.

TABLE IV—EFFECTS OF CHLOROPHENOXYACETIC ACIDS ON FRUIT SET AND VEGETATIVE GROWTH OF PLANTS. SPRING CROP, 1944

Treatment (Whole Plant Sprayed)	Flowers Setting Fruit (Per Cent)			Height of Plants (Cm) Days After Spraying Begun:	
	First Cluster	First Three Clusters	All Five Clusters	12	21
Tap water (Controls)	84	75	68	75	93
ClPA 5....	80	69	59	77	96
ClPA 5+NOA 10..	83	70	62	77	98
Cl_2PA 2½*	77	66	52	79	105
Cl_2PA 2½+NOA 10	91	67	64	78	99

*Dichlorophenoxyacetic acid (Cl_2PA) at 2½ ppm.

Because of these effects, the Cl_2PA spray was omitted after the third application (third week). The presence of NOA in the chlorophenoxyacetic acid sprays did not seem to have any modifying effects. Height measurements of all plants after 12 and 21 days from beginning of the treatments are given in Table IV. The total fruit set was not increased but the size appreciably so on all plants receiving the ClPA and ClPA + NOA treatments resulting in an increased yield of the crop by 37 to 50 per cent (Table V).

TABLE V—EFFECTS OF CHLOROPHENOXYACETIC ACIDS ON YIELD AND SIZE OF TOMATOES. SPRING CROP, 1944. FEBRUARY 5 (SPRAYING BEGUN) — JUNE 5 (LAST PICK). AVE. PER 10 PLANTS

Treatment (Whole Plant Sprayed)		No. of Fruit Harvested	Increase or Decrease Due to Treatment (Per Cent)	Total Wt of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)	Ave Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)
Tap water (Controls)	a	122	—	17,315	—	141.1	—
	b	132	—				
ClPA 5	a	154	+26.3	23,769	+37.4	154.3	+ 9.3
	b	42	−68.2				
ClPA 5+NOA 10	a	165	+35.2	26,005	+50.2	157.6	+11.7
	b	20	−84.9				
Cl_2PA 2½	a	111	− 9.0	16,401	− 5.3	147.8	+ 4.7
	b	46	−65.2				
Cl_2PA 2½+ NOA 10	a	120	− 1.6	18,583	+ 7.3	154.9	+ 9.8
	b	17	−87.1				

a Above 85 grams in weight.
b Below 85 grams in weight.

In this and later experiments all harvested ripe fruit were separated into two sizes. Those below 85 grams in weight were considered "unmarketable" and disconsidered in yield records.

The striking reduction in the number of small fruit was an outstanding feature of the crop sprayed with chlorophenoxyacetic acids. *When applied to the whole plant,* these chemicals, however, had a specific, perhaps undesirable, effect not only on vegetative structures but also the fruit of this spring crop of tomatoes. Although Cl_2PA was given only thrice, up to the time when the first fruit were only 2 cm in diameter, all fruit had been changed in development. At maturity they were unusually large, mostly pointed, softer and of an

TABLE VI—EFFECTS OF CHLOROPHENOXYACETIC ACIDS ON FRUIT SET AND VEGETATIVE GROWTH OF PLANTS. LATE SPRING CROP, 1944

Treatment (Flower Clusters Only Sprayed)	Flowers Setting Fruit (Per Cent)			Height of Plants (Cm) Days After Spraying Begun:	
	First Clusters	First Three Clusters	All Five Clusters	18	30
Tap water (Controls)	82	54	49	69	90
NOA 50	81	62	53	71	93
ClPA 5 . .	87	60	48	73	94
ClPA 10	81	64	49	71	90
ClPA 20	85	68	53	67	88
Cl_2PA 5......	85	60	46	67	88
Cl_2PA 10	85	65	48	71	93

orange color (less lycopene?). A few were ribbed and puffy. These structural features were exhibited to a much less conspicuous degree also by tomatoes from plants receiving a more prolonged treatment with ClPA. (Fig. 3)

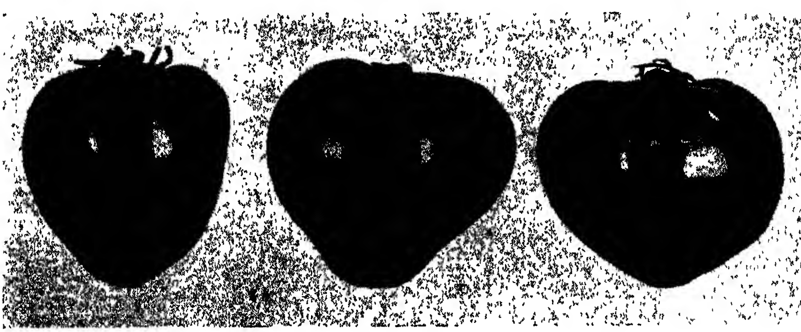

FIG. 3. Slight modification in form of Marglobe tomatoes sometimes occurs when the flowers are sprayed with *p*-Chlorophenoxyacetic acid at 10 ppm.

We were now intrigued by the powerful effects of the chlorophenoxyacetic acids and made another effort to treat a late spring crop of tomato plants. To obviate or reduce the undesirable morphogenetic effects when the whole plant is sprayed, *flower clusters only were treated* with various concentrations of ClPA and Cl_2PA, using NOA at 50 ppm for comparison, as detailed in Table VII. The chemicals were applied once a week, by means of a small hand sprayer, beginning on April 1, when 70 to 80 per cent of the flowers on basal clusters were open. Each flower cluster was sprayed twice, first when 4 to 6 flowers were open and the second time a week later, when practically all flowers had opened and some fruit had set already. All open flowers were tapped every second day to facilitate pollination.

The weather was cloudy during April, unusually so for this time of the year in Missouri. Commercial growers in Kansas City, Mo., and elsewhere had difficulty in securing a satisfactory fruit set on their late spring tomato crop. Early in May it turned clear and hot, re-

TABLE VII—EFFECTS OF CHLOROPHENOXYACETIC ACIDS ON YIELD AND SIZE OF TOMATOES. LATE SPRING CROP, 1944. APRIL 1 (SPRAYING BEGUN) — JULY 3 (LAST PICK). AVE. PER 10 PLANTS

Treatment (Flower Clusters Only Sprayed)	No. of Fruit Harvested	Increase Due to Treatment (Per Cent)	Total Wt of Fruit (Gms)	Increase Due to Treatment (Per Cent)	Ave Weight of Fruit (Gms)	Increase or Decrease Due to Treatment (Per Cent)
Tap water (Controls)	93	—	12,440	—	134	—
NOA 50	121	+30.1	15,862	+27.5	131	−2.2
ClPA 5	110	+18.3	15,458	+24.3	141	+5.2
ClPA 10	131	+40.9	18,184	+46.2	139	+3.7
ClPA 20	145	+55.9	21,070	+69.4	145	+8.2
Cl_2PA 5	144	+54.8	20,818	+67.3	145	+8.2
Cl_2PA 10	147	+58.1	21,339	+71.5	145	+8.2

maining so more or less through May and June. On July 3 the experiment was closed. In order to reduce to some extent excessive light and temperature in the greenhouse, the glass was whitewashed and a muslin curtain was drawn on the west side of the experimental plants. Even then, on exceptionally sunny and hot days, the temperature sometimes rose to 100 to 105 degrees F in the afternoon.

The height of all plants was measured after 18 and 30 days from the beginning of the experiment. The records, given in Table VI, show no influence on vegetative extension under the existing conditions. Apparently stimulation of vegetative development, brought about by the growth substances, applied to flowers only, was not great enough or it was promptly neutralized by inhibiting effects of an increased crop (size) of the fruit. The percentage of flowers setting fruit on the first clusters was increased very slightly, if at all, but noticeably so on the second and third clusters. This evened out subsequently, giving about the same set on the five clusters of sprayed and control plants (Table VI). But since the number of fruit harvested per plant was larger from all treatments by 18 to 55 per cent (Table VII), it is evident that fewer flowers were produced on the sprayed plants — an inhibition of flower development by fruit within the cluster. Fruit on "hormone" treated plants made a more rapid and more uniform growth than on controls. (Fig. 4)

The striking improvement in total yield of 24 to 71 per cent was due primarily to a greater number of fruit produced (Table VII). Within limits, the higher the concentration, from 5 to 20 ppm, of ClPA used the greater the increase in yield (24.3 to 69.4 per cent). Cl_2PA at 5 and 10 ppm was just as satisfactory in this respect as the highest concentration of ClPA used, were it not for the more pronounced effects on the form of fruit. Many of them were pointed and a few ribbed and soft, conspicuously so from Cl_2PA, 10 ppm. This was less frequently the case among the various batches of harvested fruit when ClPA was used. Every tomato was solid, however, and marketable.

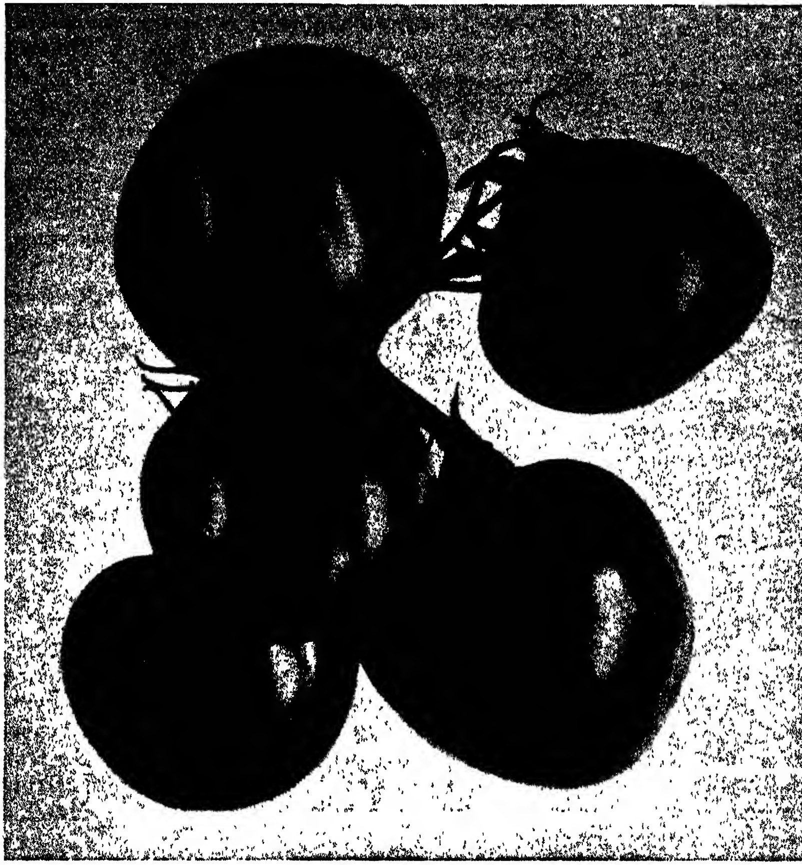

FIG. 4. Comparatively uniform development (size) of fruit due to flower spraying with *p*-Chlorophenoxyacetic acid, 10 ppm.

DISCUSSION AND SUMMARY

There does not seem to be any doubt left that fruit setting and size of tomatoes grown in greenhouses can be improved by the application of certain synthetic plant "hormones" ("growth substances"). This appears to be true when the light and temperature are subnormal, precluding to a large extent pollination and seed formation. It is not yet known whether under excessively high temperature and long days, which, according to Hoffman (3) are harmful to fruit setting of tomatoes, such sprays may have some value also. In general, they should not be considered as substitutes for, but supplementary to pollination.

Of the many chemicals used, β-naphthoxyacetic acid (NOA) and chlorophenoxyacetic acids (ClPA and Cl_2PA) seem to be especially potent for this purpose (2, 9, 8). The first (NOA) has been tested

most extensively and the most effective concentrations are fairly well known. For flower cluster spraying it should be used in an aqueous solution at 50 to 100 ppm, for spraying the whole plant at 20 ppm, applied once a week. When so used NOA does not seem to have any undesirable formative effects either on the tomato plant or its fruit.

The more recently discovered chlorophenoxyacetic acids are far more potent in their influence on the tomato and many other plants. They have not yet been tested sufficiently but appear very promising indeed. As a flower cluster spray on greenhouse grown tomatoes, applied twice, we have found *p*-chlorophenoxyacetic acid (ClPA), 10 ppm, quite satisfactory. In partly cloudy weather of late spring or early summer it may possibly be used even at as high a concentration as 20 ppm without too much risk. In cloudy weather of late fall and winter months, when pollination is difficult, this chemical, at the higher concentrations, may cause the pericarp to grow in excess of the placental tissue and result in the production of too "puffy" fruit. Roberts and Struckmeyer (8) seem to have used successfully 2,4-dichlorophenoxypropionic acid at 7.5 ppm. Other homologues of the above chemicals, such as naphthoxypropionic, ortho-chlorophenoxypropionic, 2, 4-dichlorophenoxyacetic acids, should be submitted to further extensive tests on tomato plants. It is highly probable that among these and other related groups of substances (11) even more desirable chemicals may be found for this particular purpose.

In addition to an increase in number of fruit per plant and in their size, these "hormone" sprays usually tend to make the fruit more uniform in size or weight. This is of considerable advantage in marketing. The pointed, ribbed and puffy forms, appearing to some extent when chlorophenoxyacetic acids are used, may not be of a great disadvantage, if the fruit is not too soft. We are used to puffy fruit coming in winter from the southern states and elongated (pointed) ones may be preferred for slicing.

The formative effects on fruit by some of these chemicals suggest that they stimulate directly or indirectly growth of the outer region of the pericarps. The more seeds are present the better the development of placental tissue and the more solid the fruit. Both of these conditions seem to be linked with weather (sunlight) and nutrition of the plant as a whole. It may have a connection also with the amount and distribution of naturally formed auxins in the tomato. The quality of the fruit seems to be the same whether "hormone" sprayed or not, as much as can be judged by taste. In agreement with the result obtained by others (5), repeated determinations of ascorbic acid (Vitamin C) showed no difference between treated and not treated fruit harvested on the same day.

Growth substances, when sprayed on the whole plant, had also appreciable stimulating effects on vegetative growth and on chlorophyll formation of the leaves. The first influence has been recorded several times by us, the second observed repeatedly, though no chlorophyll determinations have been made. Similar but more marked effects have been observed by us when NOA and ClPA were sprayed on pepper and bean plants (7). These formative influences on stem and

leaf development are commonly and promptly masked in the presence of a heavy crop of developing fruit as a result of their "drain" on the food supply (6). Subsequently the sprayed plants are often of smaller stature and their foliage of paler green color.

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Some Factors Affecting the Ascorbic Acid Content of Tomatoes

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A large number of investigations of the ascorbic acid content of the tomato and its products have been made. These were reviewed recently by Hamner and Maynard (2). The published data are variable and in some cases contradictory. In general, they indicate that ascorbic acid varies in relation to such factors as variety, sugar content, soil type, nutrients, and climate. Unfortunately, many investigators have not described their sampling technique and the condition of the plants from which samples were taken. It is, therefore, difficult to account for the variations and discrepancies in much of the published data. An effort has been made in these investigations to determine some of the causes of the variations in ascorbic acid content of tomato fruits.

Materials and Methods

The Early Baltimore variety was used for all tests except where another is specified. Each sample was obtained from about 15 but never less than 12 fruits selected for uniformity. Where the method of sampling is not otherwise stated, equal sectors from opposite sides of each fruit were taken. For the ascorbic acid determinations they were blended in a Waring blendor with a metaphosphoric-acetic acid mixture for one minute. The juice was then strained, centrifuged and titrated according to the method of Bessey and King (1).

The pH readings were made by means of a glass electrode. Sugars were determined by a modification of the method of Williaman and Davidson (4). Total solids represent the weight of a sample after drying to constant weight at 80 degrees F in a Brabender ventilated oven. The method used for carotenoid pigments has not been described. It consists essentially of juicing the sample, precipitation and dehydration with methanol, drying on filter paper, and dissolving with carbon disulfide. A lycopene standard was used for comparisons.

Results

Chemical Relationships:—Four strains of tomatoes were grown in replicated plots at the Cook County Experiment Station, Des Plaines, Illinois for quality studies. These in order of earliness were Illinois T19, Early Baltimore, Garden State, and Illinois Pride. Early setting fruits were removed until the latest variety began to set so that the strains would be in approximately the same physiological condition at the time of ripening. Samples were taken and analyzed September 9 (early picking period) and the results are given in Table I. The data show T19 to be comparatively low in ascorbic acid, total solids and total sugars and suggest a relationship between these constituents.

Additional studies were made at Urbana to determine whether the chemical relationships between varieties noted above would also occur

TABLE I—Chemical Composition of Four Varieties of Ripe Tomatoes Grown at Des Plaines, Illinois

Strain	pH	Vitamin C (Mgs/100 Gms)	Carotenoids (Mgs/100 Gms)	Total Solids (Per Cent)	Sugars (Fresh Wt Basis)	
					Reducing (Per Cent)	Total (Per Cent)
T19..	4.17	18.7	9.5	4.9	2.35	2.45
Early Baltimore	4.27	24.1	12.6	5.6	2.75	2.75
Garden State . .	4.37	25.2	14.0	6.15	3.30	3.53
Illinois Pride. .	4.41	27.1	11.4	5.7	2 93	3.23

within a single strain. Fruits from plants selected for varying amounts of foliage were analyzed. The plants from which the early fruits had been removed had attained larger size and after defruiting was discontinued proceeded to set and ripen a small crop. The control plants had been allowed to fruit normally. At the time samples were taken for analysis (September 20–22), the normally fruiting plants had severely defoliated, whereas the partially defruited plants had lost but little foliage and were still making new shoot growth.

The data in Table II do not agree with those in Table I to the extent of showing a relationship between ascorbic acid, total solids and sugar content. The data indicate that ascorbic acid content varies independently of total sugars. The possible inverse relationship between amount of foliage and ascorbic acid content suggested that exposure of the fruits to sunlight might be an influencing factor. This has been indicated for other fruits but apparently has not been established for tomatoes.

TABLE II—Chemical Composition of Tomato Fruits from Defoliated and Non-Defoliated Plants

Treatment	pH	Ascorbic Acid (Mgs/100 Gms)	Carotenoids (Mgs/100 Gms)	Total Solids (Per Cent)	Sugars (Fresh Wt Basis)	
					Reducing (Per Cent)	Total (Per Cent)
			T19 Ripe Fruits			
Not defoliated..	4.30	27.4	16.0	5.25	2.80	2.97
Defoliated......	4.36	28.6	15.0	4.35	2.12	2.25
		Early Baltimore—Turning Fruits				
Not defoliated.	4.11	32.4	4.2	6.10	3.30	3.48
Defoliated......	4.04	33.9	4.2	5.42	2.87	3.07
		Early Baltimore—Ripe Fruits				
Not defoliated..	4.39	28.2	14.5	6.22	3.33	3.53
Defoliated.....	4.39	36.6	17.0	6.50	2.90	2.98

Light Relationship:—Samples of fruits shaded by the plants and unshaded fruits taken from normally fruiting plants were found to have respectively 31.1 and 36.2 mgs of ascorbic acid per 100 grams of fruit. Fruits found detached from the plants gave similar results, the shaded containing 26.6 and the exposed 34.0 mgs. Further tests were made not only to substantiate this relationship between sunlight and Vitamin C but to study its distribution within the fruit relative to the geography of solar exposure.

TABLE III—Ascorbic Acid Content in Fruits Grown in Sun and in Shade

Exposure	Side Analyzed	Ascorbic Acid Mgs/100 Gms (Averages)	
Early Baltimore, Tested Sept 25, 1943			
Shade	Upper	31.1	
Shade	Lower	22.3	Shade 26.2
Sun	Upper	46.4	
Sun	Lower	31.9	Sun 39.2
Garden State, Tested Sept 30, 1943			
Shade	Upper	23.1	
Shade	Lower	19.8	Shade 21.5
Sun	Upper	37.0	
Sun	Lower	24.5	Sun 30.7
Golden Jubilee, Tested Sept 3, 1943			
Shade	Upper	25.9	
Shade	Lower	19.7	Shade 22.8
Sun	Upper	34.8	
Sun	Lower	23.9	Sun 29.4
Three Varieties			
Shade	Upper	26.7	
Shade	Lower	20.6	Shade 23.6
Sun	Upper	39 4	
Sun	Lower	26.8	Sun 33.1

Exposed and shaded fruits with axes parallel to the ground were marked as to position and harvested individually. Sectors from the upper (toward the light) and lower (away from the light) sides of the fruits were analyzed separately. Data from these tests are given in Table III. They show that exposed fruits are higher in reducing activity than the shaded ones, and that fruits of both these treatments are higher on the upper than on the lower sides. Similar results were shown by both red and yellow varieties. These data suggested that Vitamin C is concentrated in the portion of the fruit most exposed to light. A test was, therefore, made to determine the ascorbic acid content of the outer and inner portions of fruits varying in size.

Samples of medium and small unshaded fruits were marked as to position with reference to their axes and harvested. Both samples were weighed and quarter sectors from the upper and lower sides were taken from each fruit. Each sector was further divided into wall tissue and placenta including mucilaginous material around the seeds. Assays given in Table IV show wall tissue having the greatest exposure tó light to be highest and the tissue least exposed, namely, the lower placenta of large fruits, to be lowest in ascorbic acid. The

TABLE IV—Ascorbic Acid Content of Medium and Small Unshaded Fruits

Fruits				Ascorbic Acid (Mgs/100 Gms)				
				Upper		Lower		
No.	Av Wt (Gms)	Wall (Per Cent)	Placenta (Per Cent)	Wall	Placenta	Wall	Placenta	Av
16	55.6	69.1	30.9	45.2	34.3	32.2	32.2	37.0
16	121.1	58.3	41.7	62.9	31.4	34.8	29.3	41.1

larger fruits had a higher content than the smaller fruits especially in the upper wall tissue. These data are not in agreement with the work of Maclinn and Fellers (3) showing that ascorbic acid was concentrated in the gelatinous material about the seed. However, Maclinn and Fellers used greenhouse tomatoes which undoubtedly received less light exposure than unshaded field grown fruits. Their method of extraction may have favored the results from the gelatinous material over those of the wall tissue.

The ascorbic acid content of the blossom and stem ends of fruits relative to light exposure was also investigated. Fruits with the blossom end exposed to sunlight assayed 45.1 and 33.2 mgs of ascorbic acid respectively for the blossom and stem ends. Fruits having stem ends exposed showed a content of 29.7 and 39.3 mgs for respective blossom and stem ends. The stem and calyx partially shaded the fruits of the latter sample which may in part explain why they are in lower reducing activity than fruits with blossom ends exposed. The data further emphasizes the fact that ascorbic acid content varies to a greater extent with reference to sunlight exposure than with respect to the morphological region of the fruit.

TABLE V—Ascorbic Acid Content of Sun Discolored and Normally Colored Fruits Exposed to the Sun

Treatment	Ascorbic Acid (Mgs/100 Gms)		
	Upper and Lower Sectors	Side Sectors	Av
Sun discolored	41 9	43 5	42.7
Normally colored	36 1	36 1	36.1

Tomatoes exposed to sunlight often show discoloration or even injury (sun scald) depending upon the conditions of exposure. Vitamin C determinations were made on sun discolored and normally colored but exposed fruits. The data from this test given in Table V show that the ascorbic acid is higher in sun discolored than in normally colored exposed fruits. The average content of the top and bottom is very similar to that of the side sectors.

A number of determinations showed that cracked fruits were higher in Vitamin C than uncracked fruits. These tests were made after a light frost had killed some of the foliage. It was, therefore, difficult to determine to what extent a fruit had previously been shaded. Since exposed fruits seem to be more susceptible to cracking than shaded ones, it is quite likely that the difference in ascorbic acid was due to light exposure.

Conclusions

No consistent relationship has been found between ascorbic acid content, total solids, and sugar content.

Due to greater exposure to sunlight, fruits from defoliated plants may be higher in ascorbic acid content than those from plants with normal foliage.

When small samples are used to represent treatments, the fruits should be carefully selected with reference to their exposure to light.

Due to the variation in ascorbic acid from one side of the fruit to the other, careful sampling is essential when less than whole fruits are used for Vitamin C assays.

Sectors having equal angles from opposite sides of each fruit may be used to make up a sample.

Strains having dense foliage, which completely shades the fruit, may be desirable from the standpoint of sun scald but not for the production of fruit high in ascorbic acid.

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The Relative Effect of Variety and Environment in Determining the Variations of Per Cent Dry Weight, Ascorbic Acid, and Carotene Content of Cabbage and Beans

By Byron E. Janes, *University of Florida, Gainesville, Fla.*

Because of the scarcity of foods and the publicity being given the value of vitamins and minerals in the health of the nation, there is considerable interest in the nutritive value of vegetables. A large number of analyses have been made by research workers to determine what factors influence the composition of vegetables. These analyses have indicated that varieties, fertilizers, soils and climate influence the composition but, for the most part, the effects have been studied separately, so that it is difficult to determine which factors are the more important in influencing the composition of crops.

These studies were begun to determine what variations existed in the composition of Florida grown vegetables and to determine if possible what effect several environmental factors have on their composition.

Methods

During the winter of 1943 and spring of 1944 two varieties of cabbage, Early Jersey Wakefield and Copenhagen Market, were grown on plots located at the Florida Agricultural Experiment Station at Gainesville and the branch stations at Quincy, Hastings, Leesburg, Sanford, Bradenton, Belle Glade and West Palm Beach. Two varieties of beans, Tendergreen and Bountiful, were grown at Gainesville, Quincy, Hastings, Sanford, Belle Glade, West Palm Beach and Homestead. This gave a wide distribution over the state, including eight of the important soil types. There is a range of latitude of approximately 450 miles from Quincy in the north to Homestead in the south. Because of this wide range of latitude, there is considerable difference in the harvest season. The areas around Homestead and Belle Glade are distinctly winter growing areas, crops being harvested in January and February. The farther north the crops were grown, the later they were harvested, those at Quincy maturing in May.

The same lot of seed was used in all locations for both the cabbage and beans. The cabbage plants were all started at Gainesville in a single seedbed and shipped to the various places where they were grown. At each location the two varieties were grown at three fertilizer levels, one-half normal, normal, and one and one-half normal, the normal being the average amount for the particular crop, soil and area. Each treatment was duplicated, making twelve plots for each crop at each location. A graphic record of the temperature was kept at each location. Soil samples for physical and chemical analyses were taken from each plot just before the fertilizer was applied and again at the time of harvest. The crops were harvested and yield records obtained at

the time they reached commercial maturity. A representative sample from each plot was taken to Gainesville and prepared for analysis in the shortest time possible. The vitamin analyses were usually completed and samples preserved for carbohydrate and mineral analysis within 36 hours after harvest. The percentage dry weight was determined by drying two 100-gm. samples at 75 degrees C in forced draft. A modification of the Morrell method (2) was used for the determination of ascorbic acid. The method of Wall and Kelley (4) was used to determine carotene.

RESULTS

Variety, fertilizer level and location all affect the composition of cabbage and beans (Tables I to IV). From Table I it can be seen

TABLE I—AVERAGE HEAD SIZE, PER CENT DRY WEIGHT, AND ASCORBIC ACID CONTENT OF EARLY JERSEY WAKEFIELD AND COPENHAGEN MARKET CABBAGE TAKEN FROM SIX PLOTS REPLICATED ON DIFFERENT SOIL TYPES AT VARIOUS LOCATIONS IN FLORIDA**

Location	Soil Type	Head Size (Pounds)		Per Cent Dry Weight		Ascorbic Acid (Mg Per 100 Gms) (Fresh Weight Basis)	
		Early Jersey Wakefield	Copenhagen Market	Early Jersey Wakefield	Copenhagen Market	Early Jersey Wakefield	Copenhagen Market
Quincy	Marlboro fine sandy loam	1 5	2.6	6 9	6.4	51	49
Gainesville*	Arredondo	1.0	1.5	8 3	7.3	54	52
Hastings*	Bladen	1.3	1.8	10.1	9 2	54	50
Leesburg*	Norfolk fine sand	1 0	1.2	10 2	9.4	62	62
Sanford*	Leon fine sand	0.9	1.3	10.6	9.8	66	65
Bradenton*	Parkwood	2 1	2.7	9 1	8.4	59	58
West Palm Beach	Portsmouth	2.1	2.5	7.1	6.2	41	39
Belle Glade	Sawgrass peat	1 4	2.4	6.0	5 2	42	39
Average	— —	1 3	1 9	8.9	8.1	56	54

*Analyses were made of two separate harvests from these locations.
**Three fertilizer levels, ½, 1, and 1½ normal for crop and area were used at each location.

TABLE II—MEAN, AND AVERAGE MAXIMUM AND MINIMUM HEAD SIZE, PER CENT DRY WEIGHT AND ASCORBIC ACID CONTENT OF COPENHAGEN MARKET AND EARLY JERSEY WAKEFIELD CABBAGE GROWN AT ½, 1 AND 1½ TIMES THE NORMAL FERTILIZER FOR THE CROP AND LOCATION

Fertilizer Level		Average Size of Heads (Pounds)		Percentage Dry Weight		Ascorbic Acid (Mg per 100 Gms) (Fresh Weight Basis)	
		Early Jersey Wakefield	Copenhagen Market	Early Jersey Wakefield	Copenhagen Market	Early Jersey Wakefield	Copenhagen Market
½	Max.	1.5	2.0	9.3	8.7	61	60
	Min.	1.1	1.5	8 4	7 7	51	48
	Mean	1.2	1.7	9.1	8.1	57	54
1	Max.	1.6	2.3	9.1	8.4	59	60
	Min.	1.3	1.7	8.0	7.2	48	46
	Mean	1.4	1.9	8.7	8.0	54	54
1½	Max.	1.7	2.6	9.1	8.1	59	55
	Min.	1.4	2.0	7.7	7.1	49	44
	Mean	1.5	2.2	8.6	7.8	54	51

TABLE III—THE AVERAGE AMOUNT OF DRY WEIGHT, ASCORBIC ACID AND CAROTENE IN 100 GMS. OF PODS OF TWO VARIETIES OF BEANS TAKEN FROM SIX PLOTS REPLICATED ON DIFFERENT SOIL TYPES AT VARIOUS LOCATIONS IN FLORIDA*

Location	Soil Type	Dry weight (Gms)		Ascorbic Acid (Mg)		Carotene (Micrograms)	
		Tender-green	Bountiful	Tender-green	Bountiful	Tender-green	Bountiful
Quincy	Marlboro fine sandy loam	9.7	10.6	19.6	22.4	460	321
Gainesville	Arredondo	9.9	9.6	13.4	16.2	372	357
Hastings	Bladen	10.1	10.0	17.3	19 7	346	332
Sanford	Leon fine sandy loam	9.2	9 0	12.9	17.8	319	288
Belle Glade	Saw grass peat	10.2	9.7	20.2	20.8	401	366
West Palm Beach	Portsmouth	9 2	8.7	16 2	20 0	533	489
Homestead	Marl	8 2	8.0	15 7	19.6	409	343
Average	----	9 5	9 3	16.0	18.9	411	366

*Three fertilizer levels, ½, 1 and 1½ normal for crop and area, were used at each location.

TABLE IV—MEAN AND AVERAGE MAXIMUM AND MINIMUM AMOUNT OF DRY WEIGHT, ASCORBIC ACID AND CAROTENE IN 100 GRAMS OF BEANS GROWN AT THREE FERTILIZER LEVELS AT SEVEN DIFFERENT LOCATIONS IN FLORIDA

Fertilizer Level		Dry Weight (Gms)		Ascorbic Acid (Mg)		Carotene (Micrograms)	
		Tender-green	Bountiful	Tender-green	Bountiful	Tender-green	Bountiful
½ Normal*	Max	9.8	9 6	17.2	19.8	426	391
	Min.	9.4	8.9	15 1	18 1	368	297
	Mean	9 6	9.2	16.2	19.2	413	359
1 Normal	Max.	9.6	9.5	16 8	19 1	419	368
	Min.	9.3	9.2	14.0	17.8	361	305
	Mean	9.4	9.3	15.8	18.4	409	347
1½ Normal	Max.	9 9	9.8	16.9	20 3	449	388
	Min.	9 2	9 3	15 4	17.6	357	336
	Mean	9.5	9.4	16 1	19.0	409	364

*Normal is the average amount of fertilizer commonly used for beans in the particular area where grown.

that the Early Jersey Wakefield cabbage has a smaller head and a greater dry weight than Copenhagen Market cabbage. There is little difference in the ascorbic acid content between the two varieties. The greatest variation in composition occurs in plants grown at different locations. There is only a difference of .8 per cent in the average dry weight of the two varieties, while the difference between average dry weight of Early Jersey Wakefield cabbage grown at Sanford and Belle Glade is 4.6 per cent. The same magnitude of variation occurred in the head size and ascorbic acid content and for the most part the two varieties responded alike at each location.

It is impossible at this time to point out any one factor which could account for this variation from location to location but it is hoped that future studies both of the data collected for these samples and data from additional crops will show which factor or factors are responsible for the variations. These findings are in line with those of

Karikka, Dudgeon and Houck (1), who report from New York that "The Ascorbic acid content of potatoes grown in different locations showed marked variation. Whether this is due to fertilizer, soil type, climate or other condition is not known." Sheets, *et al.* (3) reported that the location had a much greater effect on the calcium and phosphorus content of turnip greens than either of several fertilizer treatments.

From Table I it can also be seen that there is a direct correlation between dry weight and ascorbic acid content, and that head size is inversely correlated with these two constituents.

As the fertilizer level was increased, the head size of cabbage increased and the per cent dry weight decreased (Table II). Fertilizer level had little or no effect on ascorbic acid content of cabbage.

The composition of beans also showed considerable variation when grown at different locations. There was a higher dry weight and carotene content and a lower ascorbic acid content in Tendergreen beans than in Bountiful beans (Table III), but here, as in cabbage, the greatest differences were from location to location. Fertilizer level had very little effect on the beans (Table IV).

Carbohydrate and mineral analyses are being made on duplicate samples of the cabbage and beans and will be reported on at a later time.

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A Continuous Supply of Fresh Sweetpotatoes for Table Use on the Farm

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It is quite possible to have a year around supply of sweetpotatoes for food on the farms in the South by using experimentally established practices. The average farmer, however, either is not well enough acquainted with the best methods or is not equipped to put them into operation. While many farmers grow enough sweetpotatoes for a year around supply, much of the crop harvested spoils, with the result that most farm families are without sweetpotatoes for a large part of each year.

To help prevent this food crop loss, experiments were conducted from 1934 through 1939 to determine a practicable combination of time of planting, time of harvesting, and methods of common storage that could be used for sweetpotatoes on the average farm with reasonable assurance that a supply would be available for home use throughout the year.

Materials and Methods

Three lots of sweetpotatoes were used in these experiments; all were harvested from early-set plants.

The first lot was harvested in 2½-pound amounts twice weekly from $^1/_{36}$-acre plots over a period of approximately 15 weeks, beginning about August 1. A part of this lot was gathered by grabbling, while some was harvested by digging. The second lot was harvested in late fall during warm weather when the soil was dry and before frost had killed the vines. The third lot was harvested after frost had killed the vines and when the temperature was generally low.

Some of the potatoes of the second harvest was stored in banks immediately after digging; others were allowed to cure for about 10 days before storage in banks. Potatoes of the third harvest were stored in banks the day harvested.

The sweetpotatoes were stored in banks of 12½- and 25-bushel capacities. The small and large banks were provided with either ventilation and shelter, ventilation without shelter, or no ventilation or shelter. The several types of banks used are illustrated in Fig. 1; a good method is illustrated in Figs. 2, 3, 4, 5, 6, and 7. Provisions were made to record the temperatures on the outside and inside of one of the large sheltered and ventilated banks. In late winter or early spring the potatoes were taken out of the banks and the amount of spoilage was determined. At this time some of those that had remained sound were re-stored in a barn loft until August 1.

Results and Discussion

Results obtained from the experiments to determine the influence of harvesting small quantities twice weekly as compared with harvests at one time are presented in the accompanying table.

TABLE I—EFFECT ON YIELD OF HARVESTING SMALL QUANTITIES OF SWEETPOTATOES TWICE WEEKLY DURING THE GROWING SEASON*

Method of Harvesting	Year	Harvests Made During Period of Root Production			Yield Per Plot (Pounds, Final Harvest)	Total Yield (Pounds)	
		Percentage of Plants Harvested	Total Potatoes Harvested (Number)	Yield (Pounds Harvested)		Per 1/36-Acre Plot	Per Acre
Check, only final harvest made	1938	0	0	0	481.60	482	17,265
	1939	0	0	0	543.54	544	19,486
	Av.	0	0	0	512.57	513	18,375
Plot harvested by grabbling 2½ pounds on Mondays and Fridays	1938	25.20	123	84.36	379.61	464	16,633
	1939	19.63	88	69.51	467.44	537	19,250
	Av.	22.41	106	76.93	423.52	500	17,956
Plots harvested by digging 2½ pounds on Mondays and Fridays	1938	18.10	160	84.86	375.95	461	16,520
	1939	14.44	121	71.74	429.77	502	17,979
	Av.	16 27	140	78.30	402 86	481	17,249

*Harvests began in 1938 on July 29 and ended on November 18. In 1939 harvests began July 31 and ended October 30. Final harvests were made on November 30 in 1938 and November 14 in 1939.

Harvesting by grabbling or by digging small quantities after the roots reached usable size limited the yield very little. Actually, the results show that grabbling limited the yield 2.28 per cent, and digging 6.13 per cent. Thus, harvesting small quantities during the late summer and fall would furnish a supply for practically 4 months in the year, when the average farmer does not have sweetpotatoes for table use. Most farmers lose a considerable quantity of their sweetpotatoes by spoilage soon after the general harvest. In view of these facts, it would be a good practice to set sweetpotato plants early and grow the crop under conditions favorable for high yields, and then harvest small quantities as needed for home use or to supply local markets when prices are good.

In the storage experiments it was found that when the potatoes were harvested before frost and stored immediately, approximately 54 per cent remained sound without ventilation or shelter; 63 per cent with ventilation; and 64 per cent with both ventilation and shelter. When the potatoes were harvested before frost and dried for 10 days before storing, 42 per cent remained sound in banks without ventilation or shelter, 47 per cent in ventilated banks, and 51 per cent in banks with both ventilation and shelter. When the potatoes were harvested after frost, slightly less than 7 per cent remained sound without ventilation or shelter, 7 per cent with ventilation, and 10 per cent with both ventilation and shelter.

These results show that even when harvested at the best time and when the best types of bank storage were used, about 36 per cent of the potatoes spoiled. In the combination of wrong harvest time and the use of best bank storage, 90 per cent spoiled. When harvested at the wrong time and stored in the poorest type of bank, 93 per cent of the potatoes spoiled.

Admittedly, the lowest losses are considerably greater than would be expected from sweetpotatoes harvested at the right time and stored

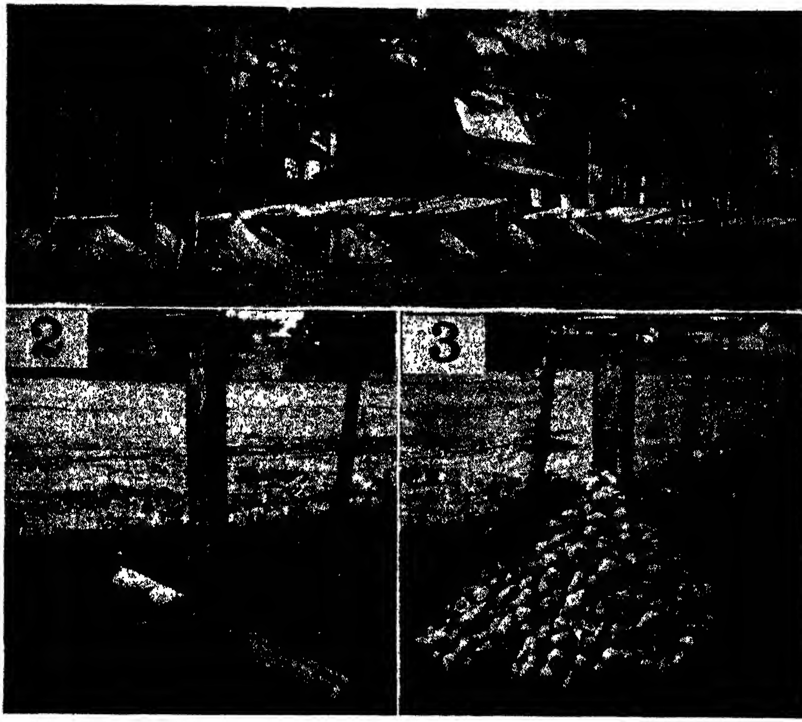

FIG. 1. Various types of banks used in the sweetpotato storage experiments.

FIG. 2. The beginning of a good sweetpotato bank with ventilators in place over several inches of straw.

FIG. 3. Potatoes in place ready to be covered with straw and cornstalks.

in houses or basements built and operated primarily for storing sweetpotatoes. Most farmers delay harvesting sweetpotatoes until after frost; furthermore, they use some form of bank storage in an attempt to save enough sweetpotatoes for use during the winter. Often they fail due to high spoilage losses. By harvesting before frost and storing in suitable banks, such heavy losses could be avoided and enough saved to provide more than an adequate supply for use during late fall, winter, and early spring.

Small and medium sized potatoes kept better than the large ones in the various type banks. When there was a relatively long cold period in which the outside temperature reached a maximum of 20 degrees F, during the day and a low of 10 degrees F, during the night, the temperature inside the bank was about 32 degrees F, or low enough to cause serious spoilage of the sweetpotatoes, such as resulted generally throughout Alabama during the winter of 1939–1940.

The dormant period of bank-stored sweetpotatoes ended by late winter or early spring, which is about the time farmers bed potatoes for plant production. Unless the potatoes were removed from the bank

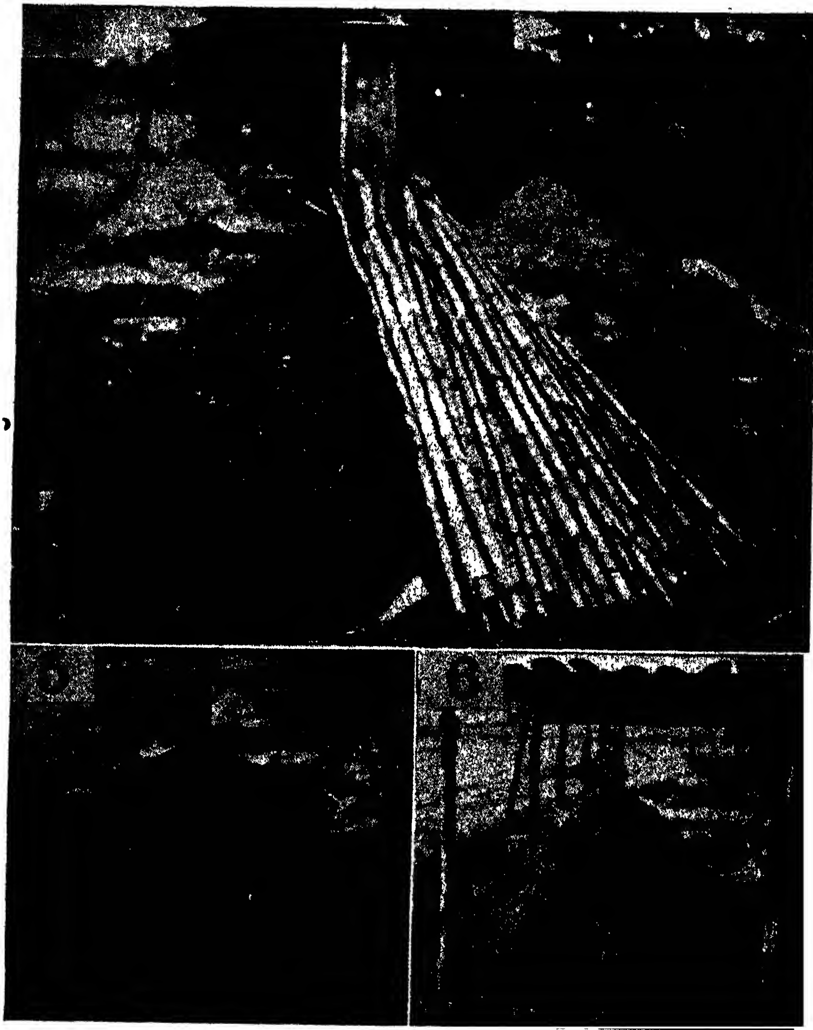

FIG. 4. The potatoes covered with straw and partially covered with stalks to show how these are applied.

FIG. 5. The straw covered with cornstalks and the stalks covered with dirt.

FIG. 6. The completed bank with a rough shed of slabs to protect it from excessive rain.

at this time or earlier, they began to sweat, sprout, crack, and spoil. However, it was found that, if they were removed from the bank, stored in small lots in a dry barn, and covered on cold nights to prevent chilling, some of the potatoes remained sound for use from late winter or early spring until August 1. Thus, this type of re-storage could be

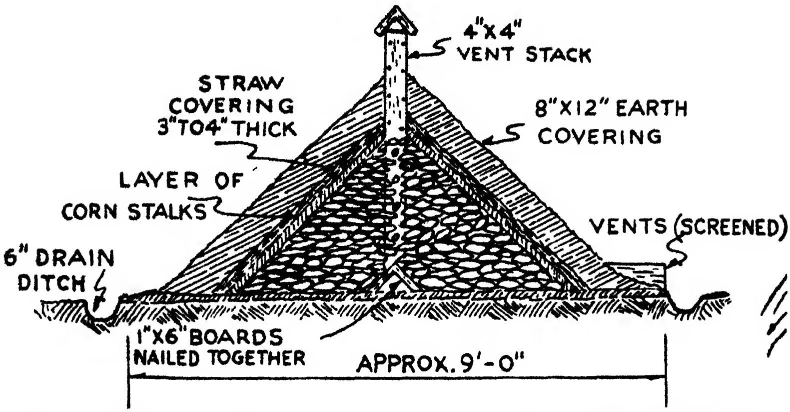

FIG. 7. Section through a good sweetpotato bank, showing the relative location of various parts.

used to supply sweetpotatoes over a period when they usually are not available for use as food on the farm.

SUMMARY

Results of experiments reported in this paper show that by combining the proper time of planting and harvesting with a good method of bank storage and restorage, it is not only possible, but practicable, for the average farmer in the South to provide a continuous supply of fresh sweetpotatoes for table use throughout the year. This may be accomplished by the following program:

1. Planting early and harvesting small quantities of the largest potatoes for current use during the summer and early fall months.
2. Harvesting in the fall before frost while the weather is warm and the soil is dry and storing immediately after harvesting in banks provided with ventilation and shelter, and enough earth or other cover to avoid chilling during the coldest weather. This will provide potatoes for fall, winter, and early spring.
3. Removing the potatoes from the bank when the dormant period is over in late winter or early spring, putting them in a dry place, and preventing chilling on cold nights. The re-stored potatoes that remain sound will provide a supply from late winter or early spring until the new crop is ready for use in midsummer.

Differences in Stability of Thiamin, Riboflavin, and Ascorbic Acid in Cabbage Varieties[1]

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The discovery that hereditary variability in the concentration of certain vitamins exists in different varieties and strains of the same kind of vegetable indicates the need for vitamin content studies as an essential part of plant breeding operations. Such studies are restricted to those vitamins which can be determined fairly rapidly; among them are ascorbic acid (vitamin C), thiamin chloride (B_1), and riboflavin (B_2). The order shown is the descending order of abundance of these vitamins in cabbage, and also of the approximate relative ease with which they can be analyzed.

In the present paper a report is given on the stability of ascorbic acid in different cabbage varieties and breeding lines as influenced by cooking and storage, and on the relative abundance and interrelationships of all three vitamins in dehydrated and dehydrated-stored products.

Materials and Methods

The three experiments described in these studies include a storage-cooking experiment, a dehydration and dehydration-storage experiment and an experiment dealing with seasonal variation in vitamin content. The cabbage was grown in the winter of 1942–1943 and spring of 1943 in randomized blocks replicated either two or four times.

In the storage-cooking experiment 10 heads of each of three strains were divided into three lots, two heads were analyzed immediately for vitamin C, four heads were placed in refrigerated storage at 4 to 5 degrees C, the other four heads were stored at room temperature. Two heads were removed and analyzed from the refrigerated and two from the room temperature lots after 1 week and the other two heads in each lot were analyzed after 2 weeks' storage. Two samples from each head were analyzed in three conditions: raw, cooked 30 minutes and cooked 2 hours. The above sampling was carried out at 3-day intervals for three harvesting dates (December 30, 1942, January 2, and January 5, 1943) making a total of 30 heads analyzed from each strain. The three strains used in this experiment included Round Head No. 18, a new commercial variety, and two inbred lines designated here as Volga–2 and Charles Wakefield–1.

In all cooking treatments, 50 gms of fresh cabbage were placed in 400-ml beakers with 50 ml of water. The beakers were covered with watch glasses, the contents brought to a boil and cooked for either 30 minutes or 2 hours over low gas flames. When the cooking period

[1]Paper No. 40, U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.

The authors wish to acknowledge the technical assistance of Frances Rawling Hayden and Ruth Foster Dingee in the vitamin determinations.

exceeded 30 minutes, additional portions of water were required. The beakers and contents were weighed before and after cooking and enough water was added to bring the final weight back to its original value. Fifty milliliters of 2 per cent metaphosphoric acid solution were added and the ascorbic acid determined by a modification (3) of the procedure described by Morell (5). The analysis of variance was made of data from a split-plot design as given by Hayes and Immer (2).

In the dehydration and dehydration-storage experiment about 12 heads of each of seven strains were shredded, with cores removed and approximately half of the cabbage in each lot, with one exception, was mixed separately to make 13 samples suitable for dehydration studies. Each sample was analyzed for vitamins B_1, and B_2 and C at three periods, before blanching and dehydration (June 17, 1943), immediately following dehydration (June 18) and after 3 months storage (September 24) of the dehydrated products at room temperature in air-tight glass jars. The seven strains used in this experiment included the four commercial varieties, Copenhagen Market, Round Head No. 18, Marion Market, and Charleston Wakefield and the three breeding lines Volga-1, Volga-2 and Charleston Wakefield-1.

The dehydrator employed was a laboratory-size tray drier of about 300 pounds capacity, of the inclined tunnel type heated by steam radiators. Air movement over the trays was maintained by a fan. Recirculation of air to any desired degree was possible, and any suitable temperature could be closely maintained. The apparatus was operated essentially as a center exhaust dehydrator, the fresh material being inserted and drying completed both at the hot end.

Blanching was performed in a separate unit in steam for 4 minutes at 188 degrees to 208 degrees F. The initial drying temperature was 180 degrees F for less than 2 hours, after which it was gradually reduced to not exceed 145 degrees F. All varieties were dried within 8 hours to about 5 per cent moisture (average 4.98 per cent), and immediately afterwards all material was sealed in air-tight glass jars.

Thiamin was determined by a modification of Conner and Straub's (1) procedure. Fifty grams of fresh cabbage or 5 gms of dehydrated cabbage were ground in a high-speed mixer with 100 ml of .04N sulfuric acid, then transferred to a 250 ml pyrex volumetric flask with approximately 75 ml of .04N sulfuric acid and heated for 30 minutes in a boiling water bath. After cooling, sufficient sodium acetate-acetic acid buffer was added to bring the extract to a pH of 4.3–4.5. One-tenth gram each of takadiastase and papain were added to each sample and the digestion allowed to continue overnight at a temperature of 40 degrees C. After making to volume and filtering, aliquots were run through Decalso adsorption columns as described by Conner and Straub.

Another aliquot of the same filtrate was used for riboflavin determination, in which the MacKinney and Sugihara (4) procedure was used. All steps of the thiamin procedure up to the adsorption on the columns and the entire riboflavin procedure were carried out in a darkened room. Blanks for the riboflavin determination were secured

by re-reading the samples after adding sodium hydrosulfite to the tubes. All fluorometric readings were made with a Coleman photofluorometer and calculations were based on standardized curves obtained from pure thiamin or riboflavin solutions. Covariance analysis of Snedecor (6) was used for interpreting the results of treatment and varietal differences in ascorbic acid with and without the interaction of the two B vitamins.

In the third experiment five commercial varieties were analyzed in the fresh state in February and in June to determine the influence of season on the ascorbic acid and thiamin content.

Results

I. Stability of Ascorbic Acid During Storage and Cooking:—A split-plot variance analysis of the storage and cooking treatments was used on 540 samples distributed equally among the three cabbage strains, Round Head No. 18, Volga–2 and Charleston Wakefield–1. The results are summarized in Table I. The Volga–2 breeding line contained significantly more ascorbic acid in the fresh state than the other two strains and lost it at a somewhat slower rate in storage. Although Volga–2 probably lost ascorbic acid just as rapidly as Round Head No. 18 in refrigerated storage, it retained considerably more at room temperature storage (see uncooked lots, Table I).

All strains lost ascorbic acid rapidly and at approximately the same rate in the cooking treatments. The averages for all strains indicate that cooking is much more destructive to ascorbic acid than storage for one or two weeks in a refrigerator or at room temperature. During 30 minute and 2 hour cooking periods, 53.4 per cent and 85.9 per cent respectively of the ascorbic acid was destroyed. Storage losses alone did not exceed 20.8 per cent in any case. The uncooked cabbage that had been stored 2 weeks in the refrigerator lost 11.0 per cent of its ascorbic acid on the average when compared to the unstored uncooked cabbage. The uncooked cabbage that had been stored 2 weeks at room temperature lost 11.4 per cent of its ascorbic acid.

II. Stability of Vitamins B_1, B_2 and C During Dehydration and Later Storage:—Table II shows that during dehydration vitamin C (84.2 per cent loss) is about ⅓ as stable as B_1 (29.9 per cent loss) and that B_2 (43.4 per cent gain) appears to have increased in quantity. All strains showed a significant loss of B_1 and C during dehydration Most of the strains tended to increase in B_2 although Volga–1, Volga-2 and Charleston Wakefield were the only strains that showed a significant increase. The direction of change observed upon dehydration continued into storage of the dehydrated product for vitamins B_1 and C and in most instances for B_2. At the end of the three months storage period the content of none of the vitamins in the individual strains, with the exception of B_2 in Marion Market, Charleston Wakefield–1 and Volga–2, was significantly different from the content immediately following dehydration. However, the averages of all strains were significantly different at the 5 per cent level for vitamins B_1 and B_2.

TABLE I—STABILITY OF ASCORBIC ACID IN THREE CABBAGE STRAINS AS INFLUENCED BY SEVERAL STORAGE AND COOKING TREATMENTS. AVERAGES OBTAINED FROM SUMS USED IN THE SPLIT PLOT VARIANCE ANALYSIS

Treatments*	Strains							
	Round Head No. 18		Volga—2		Charleston Wakefield—1		Average for All Strains	
	Mg/100 Gm Fresh Wt	Per Cent Change in Treatment	Mg/100 Gm Fresh Wt	Per Cent Change in Treatment	Mg/100 Gm Fresh Wt	Per Cent Change in Treatment	Mg/100 Gm Fresh Wt	Per Cent Change in Treatment
Unstored								
Uncooked	45.6	—	66.7	—	62.1	—	58.1	—
Cooked 30 min	22.8	—	29.0	—	31.2	—	27.7	—
Cooked 2 hrs	4.4	—	12.0	—	13.6	—	10.0	—
Average**	24.3	—	35.9	—	35.6	—	31.9	—
Stored 1 Week in Refrigerator								
Uncooked	48.9	+7.2	61.5	−7.8	56 5	−9.0	55.6	−4.3
Cooked 30 min.	27.1	—	31.9	—	27 4	—	28.8	—
Cooked 2 hrs	7.8	—	7.0	—	6.1	—	7.0	—
Average**	27.9	+14.8	33.5	−6.7	30 0	−15.7	30.5	−4.4
Stored 1 Week at Room Temperature								
Uncooked	42.0	−7.9	64.5	−3.3	53.8	−13.4	53.4	−8.1
Cooked 30 min.	16.9	—	28.7	—	22.9	—	22.8	—
Cooked 2 hrs	7.5	—	9.5	—	8.4	—	8.5	—
Average**	22.1	−9.0	34.2	−4.8	28.4	−20.2	28.2	−11.6
Stored 2 weeks in Refrigerator								
Uncooked	43.0	−5.7	63.0	−5.5	49.2	−20 8	51.7	−11.0
Cooked 30 min	22.5	—	30.4	—	23.5	—	25.5	—
Cooked 2 hrs	6.9	—	10.0	—	4.6	—	7.2	—
Average**	24.1	−0.8	34.4	−4.2	25.8	−27 5	28 1	−11.9
Stored 2 Weeks at Room Temperature								
Uncooked	36.2	−20.6	62.5	−6.3	55.7	−10.3	51.5	−11.4
Cooked 30 min	15.8	—	28.3	—	20.4	—	21.5	—
Cooked 2 hrs	4.8	—	7.9	—	4.0	—	5.6	—
Average**	18.9	−22.0	32.9	−8.3	26.7	−25.0	26.2	−17.9
Average uncooked†	43.1	—	63.6	—	55.5	—	54.1	—
Average cooked 30 min†	21.0	−51.3	29.6	−53.5	25 1	−54.4	25.2	−53.4
Average cooked 2 hrs†	6.3	−85.4	9.3	−85.4	7.3	−86.8	7.6	−85.9
Average all treatments‡	23.5	—	34.2	—	29.3	—	29.0	—

*Each strain contributed 30 heads gathered in 10-head groups on three different harvesting dates. Each group was divided into three lots (1) two heads were analyzed immediately after harvest, (2) four heads were stored in a refrigerator, 4 to 5 degrees C, and (3) four heads were stored at room temperature. Two heads were analyzed after 1 week and the other two heads after 2 weeks from each of refrigerated and room temperature storage lots. All heads were analyzed in duplicate in three conditions: uncooked, cooked 30 minutes, and cooked 2 hours.

**Significant difference at 1 per cent level for averages of "storage" treatments within strains = 1.5 mg; for the average storage treatment of the average of all strains = 0.8 mg. Each storage treatment average within strains was secured from 36 analyses, *i.e.* 2 heads × 2 samples × 3 harvests × 3 cooking treatments.

†Significant difference at 1 per cent level for averages of "cooking" treatments within strains = 0.8 mg., for the average cooking treatments for the average of all strains = 0.4 mg. Each cooking treatment average within strains was secured from 60 analyses, *i.e.* 2 heads × 2 samples × 3 harvests × 5 storage treatments.

‡Significant difference at 1 per cent level between strains for the average of all treatments = 3.1 mg.

TABLE II—CONTENT OF VITAMINS B_1, B_2 AND C IN SEVEN CABBAGE STRAINS IN THE FRESH STATE, IMMEDIATELY FOLLOWING DEHYDRATION, AND AFTER 3 MONTHS' STORAGE OF DEHYDRATED PRODUCT*

Treatment**	Vitamins per 100 Gms Fresh Weight								
	Copenhagen Market (Commercial)	Round Head No. 18 (Commercial)	Marion Market (Commercial)	Volga —1	Charleston Wakefield (Commercial)	Charleston Wakefield —1	Volga —2	Average of All Strains: In Units†	Average of All Strains: Per Cent of Change
				Vitamin B_1 Micrograms					
Fresh	56.4	65.7	73.3	78.0	69.5	83.4	63.7	70.0	—
Dehydrated	39.9	45.0	55 6	55.1	52.5	51.4	44.9	49.2	−29.9
Dehydrated and stored 3 months	32.6	39.0	48.8	49.7	43 0	46.1	43.8	43.3	−38.2
Average‡	43.0	49.9	59 2	60 9	55.0	60.3	50.8	—	—
				Vitamin B_2 Micrograms					
Fresh	16 9	16.9	21.1	28 2	29.5	33.7	44.0	27 2	—
Dehydrated	16 6	28.1	27 1	42 8	52.0	41.2	65.3	39.0	+43.4
Dehydrated and stored 3 months	23.3	36 9	38.6	44 1	44.1	52.8	77 5	45.3	+66.7
Average	18.8	27.3	28 9	38.4	41.9	42.6	62.3	—	—
				Vitamin C- Milligrams					
Fresh	33 4	33 5	40 6	46 8	37.8	40.5	53.2	40.8	—
Dehydrated	5.5	4 1	6.2	6 1	5.9	7.8	9.1	6.4	- 84.2
Dehydrated and stored 3 months	3 4	3 2	4 3	4 0	2.9	4.1	6.1	4.0	−90.4
Average	14 1	13 6	17 0	19.0	15.5	17.5	22.8	- -	—
No. of heads	11	13	12	13	13	15	6		

*About 12 heads in each of seven strains were cored and shredded, and approximately half of the cabbage in each lot, except Volga—2, was mixed separately to make 13 large samples; these were analyzed as indicated above. (Exact number of heads shown in the table)

**Significant differences at 5 per cent level for treatments within strains = 14.8 micrograms for B_1, 11.5 micrograms for B_2, and 6.9 mg for C. Each figure represents the average of 2 samples.

†Significant differences at 5 per cent level between treatments for the averages of all strains = 5 6 micrograms for B_1, 4 3 micrograms for B_2, and 2.6 mg for C. Each figure represents the average of 14 analyses, 2 samples × 7 strains.

‡Significant differences at 5 per cent level between strains for the average of all treatments = 8.9 micrograms for B_1, 6.4 micrograms for B_2, and 4 0 mg. for C. Each figure represents the average of 6 analyses, 2 samples × 3 treatments.

Judged by strain averages for all treatments, Volga–1 and Charleston Wakefield–1 were significantly superior to Copenhagen Market, Round Head No. 18 and Volga–2 in B_1 content. In the averages for all treatments, the B_2 content of Copenhagen Market is significantly lower and Volga–2 is significantly higher than that of any other strains. Both Volga breeding lines tend to lead the remaining 5 strains in both original and final content of vitamin C. The lead of Volga–2 is significant over all except Volga–1.

The general order of ranking of these strains for riboflavin was similar to that indicated for ascorbic acid but this order does not hold for thiamin chloride. Further explanation of the occurrence of this association is given in Table III. When compared with vitamin C, dehydration and storage had relatively little effect on the B_1 content and what variability was exhibited in the variance data was almost eliminated in the covariance data when C was the independent

TABLE III—RELATIONS BETWEEN ASCORBIC ACID (C), THIAMIN CHLORIDE (B_1) AND RIBOFLAVIN (B_2) IN SEVEN CABBAGE STRAINS BASED ON ANALYSES MADE IN FRESH STATE, IMMEDIATELY FOLLOWING DEHYDRATION AND AFTER 3 MONTHS' STORAGE OF THE PROCESSED PRODUCT

Vitamins Studied in Regression as: Dependent Variable	Vitamins Studied in Regression as: Independent Variable	Sources of Variability	F Values of the Dependent Variable When: Independent Variable is Included	F Values of the Dependent Variable When: Independent Variable is Eliminated	Coefficient of Correlation: Total Data	Coefficient of Correlation: Data From Fresh Cabbage
B_1	C	Treatments	62.62**	3 10	+0.981	
		Strains	8.14*	9.73**	+0.300	+0.253
B_1	B_2	Treatments	62.62**	10.67**	−0 990	
		Strains	8.14*	9.96**	+0.124	+0.361
B_2	C	Treatments	42.29**	4 88*	−0 943	
		Strains	65.75**	25.37**	+0.877**	+0.849*
B_2	B_1	Treatments	42.29**	4.97*	——	
		Strains	65.75**	68.65**	——	
C	B_1	Treatments	636.57**	39.48**	——	
		Strains	6.39**	5 10*	——	
C	B_2	Treatments	636 57**	87.68**	——	
		Strains	6.39**	1 27	- -	
Significance levels			5 per cent / 1 per cent	5 per cent / 1 per cent	5 per cent	1 per cent
		Treatments	4 46 / 8.65	4.74 / 9.55	0 997	1.000
		Strains	3.58 / 6 37	3.87 / 7 19	0.754	0.874

*Significant at 5 per cent level.
**Significant at 1 per cent level.

variable. The variance for B_1 was also reduced, but not below the original significance level, when B_2 was the independent variable. The variability for strains was increased for B_1 in the covariance data with either of the other vitamins as the independent variable. The B_2 variability in variance, due to treatments, was reduced when adjusted for either of the other vitamins. The reduction was slightly greater with ascorbic acid than with thiamine. Ascorbic acid variance data remained unchanged in significance in the covariance data when treatments were considered with either B_1 or B_2 as the independent variable. When strains are considered, a highly significant figure for B_1 was only slightly reduced in the covariance data but a highly significant figure for B_2 was reduced to nonsignificance. Data on correlation coefficients for all possible associations show a highly significant coefficient, .877, between riboflavin and ascorbic acid for the strains when all the data are considered and a significant coefficient of .849 when only data from fresh cabbage are considered.

III. Seasonal Differences in Vitamin Content:—The first five strains of the preceding experiment were harvested in both February and June and analyzed for Vitamins B_1 and C. The data in Table IV show that the seasonal differences for the averages of all strains were significant for each vitamin. The B_1 content was higher in June and the C content was higher in February. Seasonal differences were significant for three individual strains for each vitamin, but Marion

TABLE IV—INFLUENCE OF DIFFERENT SEASONS, FEBRUARY AND JUNE, ON CONTENT OF VITAMINS B_1 AND C IN FRESH SAMPLES OF FIVE CABBAGE STRAINS

Strain	Vitamins per 100 Gm Fresh Weight					
	B_1 (Micrograms)			C (Milligrams)		
	Feb	June	Seasonal Differences	Feb	June	Seasonal Differences
Copenhagen Market	51.2	56.4	5.2	39.3	33.4	5.9*
Round Head No. 18	58.9	65.7	6.8	42.5	33.5	9.0*
Marion Market	63.8	73.3	9.2*	49.1	40.6	8.5*
Volga—1	56.2	78.0	21.8**	43.1	46.8	3.7
Charleston Wakefield	56.6	69.5	12.9*	40.9	37.8	3.1
Average	57.3	68.6	8.7*	43.0	38.4	5.6*

*Significant difference for seasons at 5% level.
**Significant difference for seasons at 1% level.
Differences required for significance between seasons:

	B_1	C
5 per cent level	8.2	4.0
1 per cent level	13.5	6.7

Each figure in the February data represents an average of six samples while in June each figure represents an average of two samples.

Market was the only strain that showed a significant seasonal difference for both vitamins. This strain contained more B_1 in June and more C in February. Volga–1 and Charleston Wakefield contained significantly more B_1 in June than in February. Copenhagen Market and Round Head No. 18 contained significantly more vitamin C in February than in June. Volga–1 was the only strain that contained more ascorbic acid in June than in February, lacking only 0.3 mg from being significant at the 5 per cent level.

The only significant difference between strains in B_1 content occurred in June. Although Volga–1 contained more B_1 than any other strain, it was only significantly higher than Copenhagen Market. In February, Marion Market contained significantly more vitamin C than any of the other strains except Volga–1. In June, Volga–1 contained significantly more C than any of the other strains except Marion Market.

DISCUSSION

Although the quantity of ascorbic acid in cabbage is much greater than that of thiamin or riboflavin, this initial advantage is somewhat offset by the greater ease with which it is destroyed by any form of heat in preparation for table use. On the other hand, much less is lost while cabbage is stored in the whole, untreated state for two weeks at room temperatures. The data from three strains tested in the storage-cooking study indicate that strain differences exist in the stability of ascorbic under storage conditions, even though all three strains lost at approximately equal rate under cooking. Table I shows that the inbred line, Volga–2, not only contained more ascorbic acid at any stage of the storage treatments but also lost it at a slower rate than the inbred line, Charleston Wakefield–1. Under room storage conditions, it also lost ascorbic acid more slowly than the commercial variety Round Head No. 18 which was very variable within the variety

in ascorbic acid content. The superior ranking of the two Volga breeding lines in ascorbic acid and riboflavin, when compared with the other five strains, and the greater stability of ascorbic acid in Volga–2 is important information in the cabbage breeding program. Volga is also noteworthy in its cold hardiness and heat tolerance. Table IV shows that it was the only strain which contained more ascorbic acid in June than in February. Its vitamin B_1 content was correspondingly greater in June compared with February than that of any other strain.

During the unfavorable, hot August and September weather of the southeastern coastal plain, lines obtained from Volga were the only ones in the past two summers that developed heads. This variety is, therefore, of utmost importance in breeding cabbages for warm countries. Its chief drawback is a flavor which some people find disagreeable.

It is interesting to note that the concentration of riboflavin apparently increases under the dehydration heat treatment and in later storage. This interpretation must be considered tentative, however, until it is learned whether other fluorescent compounds are increased under heat treatment and hence are being confused with riboflavin.

In the seven strains represented in the dehydration experiment, the strains high in ascorbic acid were also high in riboflavin. If this association holds generally, it will be valuable in the breeding program; the simpler and more rapid ascorbic acid determination may possibly be used as a rough indication of the riboflavin content.

It should be emphasized that all commercial varieties in this test came from a single source and that stocks bearing the same names from other sources would not necessarily respond in exactly the same way.

Summary

Ascorbic acid was lost from cabbage very rapidly by heat treatments, 53.4 per cent after 30 minutes boiling, 85.9 per cent after 2 hours boiling, and 85.2 per cent after 4 minutes steam blanching and 8 hours dehydration; but it was relatively stable in the stored uncooked cabbage, losing only 11.0 per cent after 2 weeks in refrigerated storage and 11.4 per cent after 2 weeks at room temperatures.

After 8 hours dehydration 29.9 per cent of thiamine was lost, only one-third as much as the ascorbic acid loss; but riboflavin apparently increased in quantity, 43.4 per cent gain. The direction of these changes continued during storage of the dehydrated product for 3 months. Strain averages of these three vitamins for seven strains showed a significant positive correlation between ascorbic acid and riboflavin, but thiamin was independent of the other two.

An inbred line, Volga–1, contained more riboflavin and more ascorbic acid (except for another Volga line) than five other strains. When stored at room temperature, this same line, in another experiment, lost ascorbic acid at a slower rate than two other strains with which it was compared; at refrigerated temperatures, however, it retained more ascorbic acid than either of the other two strains but the

rate of loss was significantly slower than that of only one of the other strains. Copenhagen Market was inferior to any strain in yield of the two B vitamins. When five strains were grown for harvesting in February and also in June, all of them contained more thiamin and four of them less ascorbic acid in June. Only Volga showed more ascorbic acid in June, but the increment was not quite significant. Except for Marion Market, which showed a significant difference between seasons for both vitamins, those strains which had significant differences between seasons for ascorbic acid failed to show such differences for thiamin.

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A Study on the Storage of Carrots Under Home Conditions[1]

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Since 1940 there has been a great increase in the number of home gardens in this country. The fact that the carrot is an important crop in these gardens brings up the problem of finding satisfactory methods of storing it under home conditions.

Studies by Hasselbring (1) have shown that carrots lost about 7 per cent of their weight after 22 weeks of storage at 32 to 35 degrees F and 26 per cent of their weight when stored at 39 to 40 degrees F for the same length of time. Lauritzen (4), in studies on the development of storage diseases of carrots, stored carrots at various temperatures varying from 32 degrees F to 97 degrees F and at relative humidities varying from 70 to 95. Minimum losses due to decay and shrivelling occurred at a storage temperature of 32 degrees F and a relative humidity of 90 to 95 per cent. Platenius (6) stored carrots at 32, 35, 40, and 50 degrees F with the relative humidity at 93 to 98 per cent. Carrots kept for six months without serious deterioration when stored at 32 to 40 degrees F. All of the above mentioned workers stored the roots in baskets or crates such as are used in commercial storage.

Storage of carrots under home conditions where the temperature and humidity cannot be so readily controlled has not been thoroughly studied. Lloyd (5) suggested that small lots of home stored carrots could be kept best by packing the roots in boxes with alternating layers of carrots and soil or sand and placing the boxes in the coolest part of the cellar. Langley *et al.* (3) found that storing carrots in this way in a "cool, damp" cellar (temperature 43 to 54 degrees F, relative humidity 77 to 96 per cent) resulted in a loss of only 8.7 per cent in weight during 4 months of storage, while carrots stored in a similar manner in a "warm, dry" cellar (52 to 60 degrees F, 47 to 51 per cent relative humidity) lost 39.2 per cent of their weight during the same period.

A survey of storage oi carrots in the home showed that numerous other devices were being employed. However, little experimental evidence is available concerning the relative efficiency of these home storage methods under varying conditions of humidity and temperature.

Materials and Methods

Chantenay carrots for the storage study were seeded on June 24, 1943, at University Farm and were dug on October 12, at which time they were topped to within one-half inch of the crown, placed in slatted crates and taken to a cellar having a temperature of about 60 degrees F. On October 18 these carrots were sorted to remove any

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showing signs of decay. The sound roots were divided into lots varying in size from 3000 to 6000 grams.

Treatments were of two types: (a) storage in 11 kinds of containers, and (b) storage of roots with crowns intact and with crowns removed. All combinations of the above two types of treatments were studied at three temperatures, with a few exceptions, which will be brought out in the discussion of results. Each treatment was run in duplicate.

The samples were weighed at the initiation of the storage experiments (October 18) and the percentages of usable and unusable carrots were determined by weighing at approximately monthly intervals to the termination of the experiment on March 3. At each weighing the unusable carrots were discarded. The data on the per cent usable carrots were analyzed statistically using Bliss' method of angular transformation as discussed by Hayes and Immer (2).

Minimum and maximum temperatures and relative humidity were recorded daily in each cellar. These data are summarized in Table I. The three temperatures at which the storage treatments were studied were: (a) 36 degrees F, (b) 43 degrees F, and (c) 53 degrees F. The mean relative humidity at the three storage temperatures was 82 to 85 per cent during the storage period.

TABLE I—Temperature and Relative Humidity in Cellars from October 18th Through March 3rd

Cellar	Range in Rel Humidity	Mean Rel Humidity	Range in Temperature (Degrees F)	Mean Min Temperature (Degrees F)	Mean Max Temperature (Degrees F)
Cold	64-93	85	32-50	35	36
Medium	66-93	85	36-55	42	43
Warm	60-94	82	41-66	50	53

Discussion of Results

It will be noted in Table II that the per cent of usable carrots after 137 days of storage was influenced by the temperature, the type of container, and by the removal and non-removal of crowns. A discussion of the influence of these factors and their interactions follows.

Effects of Temperature:—The effects of storage temperature without regard to methods of storage on the percentage of usable and decayed carrots and on the per cent of moisture loss are shown in Table III. The data are accumulative from one date to the next. The results verify those of other workers by showing that the storage temperature is an important factor in keeping carrots in an usable condition. At the end of 42 days of storage 90 per cent of the carrots were still in a usable condition when kept at 36 degrees F or at 42 degrees F while 74 per cent of the carrots kept at 52 degrees F had adready been lost principally due to decay. As the period of storage was extended the losses at the 42 degrees F temperature and at 52 degrees F increased more rapidly than those at 36 degrees F, so that after 137 days of storage 73 per cent of the original weight of carrots stored were in usable condition when stored at 36 degrees F, while

TABLE II—EFFECTS OF METHOD OF STORAGE ON THE PER CENT USABLE CARROTS AFTER 137 DAYS OF STORAGE. (MEANS OF TWO SAMPLES)

Type of Container	Per Cent Usable Carrots in Indicated Classes						Mean Per Cent Usable Carrots With Crowns Intact
	Temperature 35-36 Degrees F		Temperature 42-43 Degrees F		Temperature 50-53 Degrees F		
	Crowns Intact (Per Cent)	Crowns Removed (Per Cent)	Crowns Intact (Per Cent)	Crowns Removed (Per Cent)	Crowns Intact (Per Cent)	Crowns Removed (Per Cent)	
1. Basket with alternate layers of carrots and							
(a) damp soil	86	—	74	—	6	41	55
(b) dry soil	—	—	—	—	24	—	—
(c) damp sand	86	—	74	—	12	43	57
2. Unlined basket with cover	53	—	34	—	0	—	29
3. Waxed-paper lined basket with cover	69	77	49	59	5	0	41
4. Friction-top can with cardboard cover							
(a) no drainage	73	73	51	66	2	0	42
(b) stone drainage	72	73	56	61	4	0	44
5. Friction-top can with tight cover							
(a) no drainage	71	34	13	28	0	0	28
(b) stone drainage	80	64	52	36	0	0	44
6. Covered crock							
(a) no drainage	75	77	67	58	9	0	50
(b) stone drainage	83	86	53	62	2	0	46
Difference necessary for significance at 5 per cent level	32	32	32	32	32	32	16

only 52 per cent were usable at 42 degrees F and only 2 per cent at 52 degrees F. Decay was the principal cause of losses at all temperatures. It is interesting to note that the ratio of losses due to decay and losses due to other causes (respiration and evaporation) was 2.9: 1 at 36 degrees F, 4.3: 1 at 42 degrees F, and 7.2: 1 at 52 degrees

TABLE III—EFFECTS OF STORAGE TEMPERATURE ON PER CENT USABLE CARROTS, PER CENT DECAYED CARROTS, AND PER CENT LOSS IN WEIGHT AFTER THE SPECIFIED NUMBER OF DAYS IN STORAGE. (MEANS OF 34 SAMPLES)

Storage Temperature (Degrees F)	Percentages After Indicated Number Days in Storage			
	42	78	105	137
*Usable Carrots**				
35-36	91	84	79	73
42-43	90	70	62	52
50-53	26	12	6	2
Decayed Carrots				
35-36	6	12	15	20
42-43	7	25	32	39
50-53	68	79	84	86
Loss in Weight				
35-36	3	4	6	7
42-43	3	5	6	9
50-53	6	9	10	12
*Difference necessary for sign. at 5 per cent level	3	7	8	7

F. In other words, losses due to decay increased somewhat more rapidly than did losses due to respiration and evaporation with rises in temperature.

Effects of Type of Container:—The percentage of usable carrots for the various types of containers used as a means of the three storage temperatures are shown in Table II. Storage of carrots between layers of damp soil or sand (treatments 1a and 1c) was more effective than storage in unlined bushel baskets (treatment 2), waxed-paper lined baskets (treatment 3), or in tightly-covered friction-top cans (treatments 5a and 5b). It is interesting to note that the greatest incidence of decay occurred when carrots were stored in containers which prevented, to a greater or lesser extent, free circulation of air around the roots (treatments 3; 4a; 4b; 5a; 5b; 6a; and 6b). It was observed that such containers created an atmosphere of high humidity immediately around the roots in some instances so high as to cause the condensation of moisture on the roots. Such moisture conditions are favorable for the growth of decay organisms. While storage in unlined baskets resulted in a low percentage of usable carrots the losses were due almost entirely to shrivelling rather than decay. Since the relative humidities maintained at all three temperatures averaged about 84 per cent for the storage period, in order to prevent excessive shrivelling either a higher relative humidity must be maintained in the storage room, or carrots must be stored in such a manner as to create a region of high relative humidity immediately around the roots. Shrivelling was reduced to a great extent by storage in various types of more or less air-tight containers. While it appears that most of the types of containers used were fairly satisfactory for the storage of carrots one must remember that the data given are means derived from samples stored at three different temperatures. As will be shown later in this paper, the effectiveness of the container is greatly influenced by the storage temperature.

As will be observed from Table II, certain of the containers were provided with "stone drainage". This "stone drainage" consisted of a 2-inch layer of stones about 1 inch in diameter in the bottom of the container. The use of such a layer to drain away the moisture which sometimes condenses on the inner walls of confining containers has been advocated by some people. As will be observed from Table II, the use of a layer of stones in the container had no significant effect on the percentage of usable and decayed carrots nor on the loss in weight. The mean per cent usable for all treatments having "stone drainage" was 44 per cent while the mean for comparable treatments not having "stone drainage" was 39 per cent.

The effects of using tightly-fitting covers on containers for storage of carrots in comparison to similar containers having loosely-fitting covers can be seen in Table II. The mean per cent usable for all containers with tightly-fitting covers was 32 per cent in comparison with a mean of 44 per cent for comparable containers with loosely-fitting covers. Thus, the use of loosely-fitting covers resulted in a significantly higher percentage of usable carrots and less decay. It was observed particularly at the higher storage temperatures that the

use of tightly-fitting covers resulted in rapid decay accompanied by odors characteristic of anaerobic fermentation.

Effects of Crown Removal:—Carrots for storage were prepared in two ways: (a) Tops were cut back to within ½ inch of the roots (crowns intact), and (b) tops were completely cut off removing at the same time part of the root crown so as to completely remove all buds (crowns removed). The effects of such crown removal on the storage of carrots are indicated in Table II. At the end of 42 days of storage those carrots with intact crowns (½-inch tops) were in better condition than those with crowns removed. However, as the storage period was extended this difference was reduced until finally after 137 days in storage carrots prepared by the two methods were approximately equal in percentages of usable roots. These results can be explained by the fact that carrots with intact crowns, while decaying less than those with crowns removed at the beginning of the storage period, began to sprout after a short rest period and this sprouting was accompanied by rapid development of decay organisms on these succulent sprouts. On the other hand, carrots whose crowns had been removed did not sprout and thus did not suffer the losses which were an indirect effect of sprouting. It would appear, then, that at temperatures conducive to the initiation of meristematic activity in the buds of carrots, the removal of such buds by cutting off the tops of the carrots may be effective in reducing storage losses.

Effects of Type of Container at Various Storage Temperatures:—The value of a container for keeping carrots in a usable condition is dependent to a large degree on the temperature at which it is used. Table IV shows the effects of different types of containers on the per cent usable carrots stored at 36, 42, and 52 degrees F. All of the types of containers used, with the exception of unlined baskets (treatment 2), were satisfactory when used at a storage temperature of 36 degrees F. However, at a storage temperature of 52 degrees F the type of container used greatly affected the per cent of usable carrots even after only a relatively short storage period.

For example, after 42 days of storage, carrots when stored at 36 degrees F were 100 per cent usable whether kept in damp soil (treatment 1a) or in tightly-covered cans (treatments 5a and 5b), but when stored at 52 degrees F, carrots in damp soil were 72 per cent usable while carrots in tightly-covered cans were completely decayed (0 per cent usable). Results given in Table IV indicate that storage of carrots in damp soil or damp sand was more successful than storage in other types of containers particularly at the higher storage temperatures, 42 and 52 degrees F.

Effects of Crown Removal at Various Storage Temperatures:—The effects of crown removal on the percentages of usable carrots are dependent on both the storage temperature and the length of the storage period. It will be seen from Table V that when stored at 36 degrees F, carrots with crowns removed tended to decay more than those with intact crowns. This was true also for carrots stored at 42 degrees F but only during the early period of storage. After storage for 137 days at 42 degrees F, the percentages of usable carrots were

TABLE IV—EFFECTS OF TYPE OF CONTAINER AND STORAGE TEMPERATURE ON THE PER CENT USABLE CARROTS AFTER THE SPECIFIED NUMBER OF DAYS IN STORAGE. (MEANS OF TWO SAMPLES WITH INTACT CROWNS)

Treatment	Per Cent Usable Carrots by Wt in Indicated Classes											
	42 Days Storage (Degrees F)			78 Days Storage (Degrees F)			105 Days Storage (Degrees F)			137 Days Storage (Degrees F)		
	36	42	52	36	42	52	36	42	52	36	42	52
1. Basket with alternate layers of carrots and,												
(a) damp soil	100	100	72	94	91	29	90	84	12	86	74	6
(b) damp sand	96	94	72	92	86	47	89	79	26	86	74	12
2. Unlined basket with cover	81	80	48	73	62	24	63	51	9	53	34	0
3. Waxed-paper lined basket	88	92	47	83	70	21	80	60	14	69	49	5
4. Friction-top can with cardboard cover												
(a) no drainage	87	90	57	81	74	18	80	68	6	73	51	2
(b) stone drainage	97	92	54	84	75	26	80	65	7	72	56	4
5. Friction-top can with tight cover												
(a) no drainage	100	94	0	96	36	0	80	21	0	71	13	0
(b) stone drainage	100	98	0	96	87	0	93	66	0	80	52	0
6. Covered crock												
(a) no drainage	94	91	59	81	84	31	79	77	12	75	67	9
(b) stone drainage	96	95	34	95	85	14	90	73	6	83	53	2
Difference necessary for sign. at 5 per cent level	12	12	12	22	22	22	21	21	21	19	19	19

equal whether the crowns had been removed or not. This has previously been explained elsewhere in this paper as being due to the increased decay of carrots which sprouted, sprouting being confined to carrots with intact crowns. In general, crown removal appears to result in increased losses due to decay. Referring to Table II, however, it will be seen that when carrots are stored in damp sand or damp soil at a temperature of 52 degrees F, less decay occurs when the crowns are removed prior to storage. Unfortunately, crown removal followed by storage in sand or soil was not tried at lower temperatures. It

TABLE V—EFFECTS OF CROWN REMOVAL AT DIFFERENT STORAGE TEMPERATURES ON THE PER CENT USABLE CARROTS AFTER THE SPECIFIED NUMBER OF DAYS OF STORAGE. (MEANS OF 14 SAMPLES)

No. Days in Storage	Storage Temperature (Degrees F)	Percentages Usable Carrots in Indicated Classes: Crowns Intact (Per Cent)	Crowns Removed (Per Cent)
42	35–36	94	87
	42–43	93	85
	50–53	36	0
78	35–36	88	78
	42–43	73	63
	50–53	16	0
105	35–36	83	74
	42–43	62	59
	50–53	6	0
137	35–36	75	69
	42–43	49	53
	50–53	3	0

would appear that removing the crowns of carrots to be stored in damp sand or damp soil may be desirable particularly under conditions when proper temperature control is difficult to attain.

Conclusions and Summary

Any method of storing carrots, to be successful, must minimize losses due to decay and to shrivelling. Results of other workers as well as those reported here indicate that proper control of temperature and humidity in the storage room are of prime importance in reducing such losses. In the present study, carrots lost 27 per cent of their weight by decay and shrivelling after 137 days of storage at 36 degrees F, 48 per cent when stored at 42 degrees F and 98 per cent when stored at 50 degrees F. While no particular attempts were made to maintain a high relative humidity in the cellars used in this study, certain of the results with different containers indicate the importance of high humidity in preventing shrivelling. Carrots stored in unlined baskets lost 32 per cent of their original weight due to shrivelling alone after 137 days of storage while carrots stored in containers which created an atmosphere of high humidity around the roots lost less than 10 per cent of their weight by shrivelling during the same period.

In home storage rooms where numerous types of vegetables are stored each in small quantities, maintaining storage temperatures and humidities satisfactory for each type of vegetable is difficult. A survey of storage of carrots in the home has shown that numerous devices are being used to prevent decay and shrivelling of carrots in lieu of proper temperature and humidity control. The present study was conducted to get experimental evidence as to the relative efficiencies of the different devices for the storage of carrots.

Type of container used is an important factor in successful storage of carrots under home conditions. Containers, such as baskets with alternate layers of damp sand or soil and carrots, covered crocks, lined baskets, and tin cans, which partially confined the atmosphere immediately around the roots, reduced shrivelling more than did open containers such as unlined baskets. The use of containers with airtight covers (friction-top cans) resulted in excessive losses due to decay.

The use of a layer of stones within the container for the drainage of condensed moisture was not effective in reducing losses due to decay.

Carrots with crowns cut off before being placed into storage decayed more than did carrots with intact crowns during the early storage period. However, later during the storage period carrots with intact crowns decayed more rapidly than did those with crowns removed so that at the end of four months' storage the percentages of usable carrots were approximately equal with the two treatments.

At a storage temperature of 36 degrees F, a significantly greater percentage of carrots were in usable condition after 137 days of storage when stored in damp sand, damp soil, tin containers, or covered crocks than when stored in unlined baskets.

At a storage temperature of 42 degrees F, a significantly greater percentage of carrots were in usable condition after 137 days of storage when stored in damp sand or damp soil than when stored in unlined baskets, lined baskets, covered crocks, or tin cans.

At a storage temperature of 52 degrees F, a significantly greater percentage of carrots were in usable condition after 137 days of storage when stored in damp soil or damp sand than when stored in other types of containers provided the carrot crowns had been removed prior to storage. Without crown removal, none of the methods of storage tried were satisfactory at this temperature.

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Asparagus Production in the Lower South With Special Reference to Time and Length of Cutting Season

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Although asparagus is grown chiefly in the northern and middle regions of the United States, there is a lively interest in extending its commercial production into the warmer parts of the South. It is generally known that asparagus does best in a temperate to cool climate, and that yields are lower and plantings are shorter-lived in the humid regions of the South than in the North. The southern limit of profitable culture, however, is not definitely known.

Experiments were undertaken at the U. S. Horticultural Field Station at Meridian, Mississippi to determine whether satisfactory spring yields could be obtained over a period of years in a single planting, in an area like south-central Mississippi. Because of the interest in "out of season" vegetables that sell at high prices, efforts were also made to determine whether asparagus could be harvested profitably in the fall of the year.

Review of Literature

Kimbrough (5), working at Baton Rouge, La. found that after 3 years an experimental planting of asparagus had virtually ceased to yield any edible product, and that fall cutting was a failure from the beginning.

Farish (1) found that at State College, Mississippi, fair yields (65 to 70 crates per acre) were obtained from spring harvests, but that fall harvests were all virtual failures — only about 20 crates per acre — over a period of 4 seasons.

Scott and others (8) working near Columbia, South Carolina, obtained satisfactory yields of 75 to 100 crates per acre on well-fertilized plots harvested over an average period of 6 weeks each spring for 4 years. Fall harvests of about 4 weeks yielded only about 40 crates per acre.

Average commercial yields in central South Carolina are only about 40 crates per acre, and in southern Georgia, 25 crates; yields in the Maryland-New Jersey area are about 105 crates; and in Oregon and Washington about 112 crates per acre.

At Ames, Iowa, a 10-year experiment by Haber (2) showed that the best total yields were obtained by cutting from about April 25 to June 15 (7 weeks) each year. Cutting for 9 weeks (until July 1) was too much, reducing the yields about 11 per cent below those of the plots harvested 7 weeks.

Jones (3) showed that at Davis, California, there was no very marked difference in total yields of plots cut for approximately 10 and 12 weeks, respectively, although the plots cut for 12 weeks yielded

[1]Died April 1, 1941.

an average of about 25 to 30 crates per acre more than the 10-week plots (240 crates) over a 6-year period. The spears of the 12-week plots were slightly smaller and more numerous.

Jones and Robbins (4) in California and Lewis (6) and Lloyd and McCollum (7) in Illinois have shown that light cutting (harvesting only 2 to 4 weeks instead of 8 to 12) in the year following planting is not harmful to yields in later years. Long-continued cutting the year after setting, however, retards development and is harmful for many years afterward.

MATERIALS AND METHODS

Seed of Mary Washington asparagus was sown in rows 3 feet apart in the spring of 1934 for growing plants for the experiment to be set in the following year. It was originally intended to segregate the male and female plants into separate rows in the experimental plots, but very few plants expressed their sex the first year. They, therefore, were left in the nursery a second year in the hope that they could be properly classified as to sex before setting in the plots in 1936. The generally adverse conditions prevented normal sex expression, necessitating the planting of roots unclassified as to sex.

The experimental area consisted of 36 plots in a Latin square, each plot containing seven rows 5 feet apart with 21 plants 2 feet apart in each row. Two buffer rows were planted on each side of the field, and there were three buffer plants between the ends of contiguous plots and at the ends of the field. The roots (or "crowns") were set in furrows 8 inches deep and the last 4 inches of filling of the furrow was done gradually after the first shoots emerged.

The field, although small and apparently of a soil texture and structure suited to asparagus, was more variable than desired and on a moderate slope. An upper corner was of Ruston sand, having an excessively drained surface and subsoil; most of the area was Ruston fine sandy loam, a well-drained soil with a friable sandy clay subsoil; and an area through the center of the field was classified as Ducker fine sandy loam, a well-drained colluvium. Commercial fertilizer (4–12–4 or 5–10–5 mixtures) was applied annually at the rate of 1500 pounds per acre. In 1938, 20 tons (per acre) of manure was cut into the soil, followed 3 weeks later by 18 per cent superphosphate at the rate of approximately 1500 pounds per acre.

The six "treatments", consisting of times and durations of harvesting or cutting, were as follows: 1. Cut in the spring; (A) Duration 4 weeks, (B) duration 8 weeks, and (C) duration 12 weeks, 2. Cut in the fall; (A) Duration 4 weeks, and (B) duration 6 weeks, 3. Cut in the spring and fall; (A) Duration 4 weeks each. In 5 years of harvesting (1937–1941) the first cuttings in the spring varied from March 18 to April 25, with the average date April 7. The fall cuttings were started September 27 to October 3 with the average date September 30. In 1937, the year after planting, each harvest season was only half the scheduled duration.

All treatments were harvested three times weekly. During warm

weather this was not often enough to prevent many shoots becoming too long and of mediocre quality before they were cut. For the purposes of this work, however, the comparative yields obtained are believed useful.

Immediately after harvest, the shoots were separated into large (over ¾ inch), medium (9/16 to ¾ inch), small (⅜ to 9/16 inch) and cull grades, cut to standard bunch length of 8½ inches and each grade weighed. In presenting the results, the large, medium and small grades were totaled and designated marketable.

The yield data were analyzed by the variance method for each year separately, and also combined.

Effect of Time and Duration of Cutting on Yields of Marketable Asparagus

Table I shows the yields of marketable asparagus in 24-pound crates per acre from the six treatments by years. The 4-week and the 8-week spring harvests increased more or less irregularly, year after year, until they yielded nearly alike in the fifth year, approximately 27 and 28 crates per acre respectively. The plots cut for 12 weeks yielded much more than the 4- and 8-weeks in the first year (cut only 6 weeks versus 2 and 4 weeks), little more in the second and third years: by the fourth year they yielded less and by the fifth year were showing unmistakable signs of progressive exhaustion.

TABLE I—Yields of Crates Per Acre of Marketable Asparagus Harvested from Six Treatments in 1937–1941, Meridian, Mississippi

Treatment	1937	1938	1939	1940	1941	Mean
Harvested in Spring						
4 weeks	5.1	18.6	22.4	22.5	26.9	19.1
8 weeks	16.0	28.0	24.4	19.8	27.7	23.2
12 weeks	23.1	29.3	26.3	16.7	13.9	21.9
Harvested in Fall						
4 weeks	4.0	9.3	3.8	3.6	5.7	5.3
6 weeks	6.4	11.7	4.0	5.3	8.2	7.1
Harvested in Spring and Fall						
4 weeks each	9.3	15.9	9.9	7.3	7.6	10.0
Difference required for significance at 5 per cent point	1.98	4.02	5.04	4.20	5.70	1.32

All harvest schedules involving fall harvesting appeared definitely harmful. Even the first years gave very poor yields, and from the third year on, the results were obviously worthless. Kimbrough (5) and Scott and others (8) have shown by chemical analysis that fall harvesting depletes the storage reserves of the crown. The plants in this depleted state apparently suffer winter damage that becomes progressively worse and from which they cannot recover.

Table II shows the percentages of the total yields that were classified as marketable, from the several treatments. Although there are considerable irregularities in the results of a single treatment from

year to year, it is evident that the marketable percentage of total yield, based on weight or number of spears, held up best in the plots harvested only 4 weeks in the spring. The 8-week spring harvests had almost as high percentages marketable, and they showed no definite trend upward or downward. The 12-week spring harvests, however, tended to produce a successively smaller percentage of marketable spears. The fall-harvested plots were distinctly lower than any of the spring-harvested plots, as a group. By the end of the experiment, only a third to a half of the weight of spears from these plots was marketable, and less than a third of the number of spears was marketable.

Yields of unmarketable spears are of little importance, therefore, are not tabulated here. If those figures are desired for any purpose, they can be calculated readily from data in Tables I and II.

TABLE II—Percentages of Total Asparagus Harvested from Six Treatments That Were Classified as Marketable, 1937–1941, Meridian, Mississippi

Treatment	1937	1938	1939	1940	1941	Weighted Average
			Based on Yield Per Acre			
Harvested in Spring						
4 weeks	96.8	65.7	86.3	68.3	81.5	76.1
8 weeks	95.5	67.0	77.3	59.2	70.9	71.2
12 weeks	95.0	64.1	66.8	55.2	59.2	67.0
Harvested in Fall						
4 weeks	45.7	52.6	27.2	29.5	33.7	37.9
6 weeks	56.4	55.5	29.8	36.0	41.5	44.3
Harvested in Spring and Fall						
4 weeks each	65.9	52.3	46.4	40.3	45.9	49.8
			Based on Number of Spears			
Harvested in Spring						
4 weeks	84.6	59.8	82.0	51.7	72.8	64.7
8 weeks	90.6	60.3	70.7	40.3	56.4	58.5
12 weeks	87.7	62.2	63.5	35.6	42.7	56.1
Harvested in Fall						
4 weeks	52.6	46.2	25.2	18.6	20.9	30.5
6 weeks	65.1	51.1	27 1	23.5	27.4	36.5
Harvested in Spring and Fall						
4 weeks each	66.5	45.2	37.9	23.5	27.8	37.8

Practical Recommendations

The results of this 5-year study of an asparagus planting at Meridian, Mississippi, fit into the general pattern of results reported by others in the South since the study was started. The yields were higher than those reported from Louisiana (5) but lower than those from Columbia, South Carolina (8), and State College, Mississippi (1).

The yields and quality of product obtained at Meridian do not appear high enough to be profitable commercially over a period of several years. Asparagus grows poorly and yields very little marketable product per acre in the lower part of the central South. The

closer to the Gulf of Mexico its culture is attempted, the poorer are the results.

If asparagus culture is to be attempted in the central or lower South no harvesting should be done in the fall. Fall yields of marketable product will be far too small to be profitable. The crop should be harvested only in the spring and for a period of no more than 8 weeks each year. This will give small yields, of doubtful profit, for the second to the fifth year or more. If the harvest season is as long as 12 weeks, the plantation will probably become exhausted rapidly and marketable yields will be exceedingly small after 3 or 4 years.

Under conditions like south-central Mississippi, small quantities of asparagus can be grown in farm gardens for home use, but the crop is not recommended for commercial production, or for town gardens where medium to high yields per unit area are necessary to justify its culture.

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Effect of Shearing on Performance of Beet Seed[1]

By Paul Work, *Cornell University, Ithaca, N. Y.*

One of the methods utilized to save labor in thinning sugar beets has been mechanical treatment of seed balls to reduce the number of seeds in each, thus decreasing the incidence of doubles, that is, of seedlings so close together that thinning is difficult. Such seed is described as being sheared or segmented. Vegetable growers have inquired as to the usefulness of this procedure in the culture of garden beets.

Canners pay a premium price for small beets and crowding in the row results in so little harm to shape or size that thinning is not commonly practiced.

For bunching for fresh market, crowding is somewhat more of a problem, causing some unevenness of size and some distortion of shape. Most growers, however, do not consider these difficulties serious and are able to adjust seeders so that thinning may be omitted.

Seed balls of beets are sheared or segmented by means of a machine designed by Professor Roy Bainer of the University of California at Davis (1). A coarse abrasive wheel forces the seed balls under a hardened shearing bar which breaks or cuts them into smaller pieces. The material is then screened and fanned to remove fine refuse and also large seed balls that have escaped the blade, using screens with round holes of $^7/_{64}$ths and $^{10}/_{64}$ths inch in diameter. Recovery is about 50 per cent of original weight but Bainer reports nearly twice as many seed segments per 100 grams after shearing as before shearing. Thus germination is within 5 per cent of that of whole seed.

In the spring of 1942 three lots of garden beet seed were procured from seedsmen and Professor Bainer kindly cooperated by shearing these samples. Tests of germination, stand, and yield are here reported.

Seeds Per Seed Ball

Three samples of 100 seed balls from each of the three unsheared and sheared lots were examined to determine the number of seeds in each seed ball. This examination of course could not reveal the viability of individual seeds. Averages of the three counts appear in Table I. Sample four was so badly shattered in shearing that a satisfactory count could not be made.

It is noted that shearing approximately doubled the number of singles and halved the number of doubles.

Germination

Four germination tests were made, one in cabinet by the State seed laboratory, one in sandy soil in flats in the greenhouse both in 1942

[1]Paper No. 270. Department of Vegetable Crops, Cornell University, Ithaca, New York. Grateful acknowledgement is made to Prof. M. T. Munn, Seed Laboratory, Geneva, N. Y., for testing seed; to Robson Seed Farms, Joseph Harris Co., and the Cooperative G. L. F. Exchange for seed samples; to Prof. Roy Bainer, University of California for shearing the seeds; and to E. C. Minnum and B. A. Hall for help in conducting the experiments.

TABLE I—EFFECT OF SHEARING ON NUMBER OF BEET SEED PER SEED BALL

Sample No.	Variety	Treatment	Percentage of Seed Balls Having Indicated Number of Seeds				
			0	1	2	3	4 or 5
1	Early Wonder	Unsheared	5	31	63	1	0
2	Early Wonder	Sheared	4	67	29	0	0
3	Detroit	Unsheared	15	27	37	17	5
4	Detroit	Sheared	—	—	—	—	—
5	Crosby	Unsheared	4	32	59	6	0
6	Crosby	Sheared	7	52	39	2	0

also a test in cabinet at Ithaca and one in the field in 1943. Results appear in Table II. It will be noted that viability had declined materially in 1943. In the case of samples 3 and 4 where serious shattering occurred, the difference is marked. Between samples 1 and 2 shearing reduced germination percentage materially but occasioned little difference between samples 5 and 6.

TABLE II—GERMINATION TESTS SHOWING NUMBER OF STRONG SEEDLINGS FROM 100 SEED BALLS

Sample No.	Variety	Treatment	State Lab. 1942	Green-house 1942	Cabinet Ithaca 1943			Field 1943		
					1*	2**	Total	1*	2**	Total
1	Early Wonder	Unsheared	73	88	26	13	52	21	7	35
2	Early Wonder	Sheared	75	69	29	6	41	17	4	25
3	Detroit	Unsheared	83	117	25	17	59	21	13	47
4	Detroit	Sheared	14	75	7	—	7	6	1	8
5	Crosby	Unsheared	77	89	18	8	34	14	6	26
6	Crosby	Sheared	76	72	21	3	27	16	5	26

*Column indicates count of seed balls showing 1 strong seedling.
**Column indicates count of seed balls showing two strong seedlings. There were a few scattered cases of triples, not here recorded separately.

YIELD TEST

In 1943 a yield test was run with six replicates in sandy loam soil at Ithaca, N. Y. Table III gives number and weight of roots per plot. Rows were approximately 17 feet long with 100 seeds planted 2 inches apart. It was from this planting that field germination figures of Table 2 were taken.

TABLE III—YIELD OF BEETS FROM UNSHEARED AND SHEARED SEED-BALLS

Sample No.	Variety	Treatment	Number	Weight (Ounces)
1	Early Wonder	Unsheared	33	99
2	Early Wonder	Sheared	26	105
3	Detroit	Unsheared	60	116
4	Detroit	Sheared	7	50
5	Crosby	Unsheared	28	101
6	Crosby	Sheared	26	70

Comparing samples 1 and 2, yields did not differ materially. Between 5 and 6 there was a distinct weight advantage for unsheared seed though it was not statistically significant due to wide variation

in plot yields. Only between samples 3 and 4 was the yield difference statistically significant. There was little evidence of damage to beets by doubling and practically all were good marketable specimens. However, the stand was rather thin due to reduced viability of seed in 1943.

Shearing would seem to be a practical means of reducing the occurrence of doubles in beets and so of reducing the labor of thinning. At the same time there is reason to believe that the practical problem of securing suitable stands of garden beets may be solved satisfactorily without recourse to either shearing or thinning by the use of planters dropping a single seed ball at a place, and by carefully adjusting the rate of seeding.

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The Effect of Spacing and Number of Kernels Per Hill on Sweet Corn Yields

By B. S. Pickett, *Texas A. & M. College Experiment Station, Weslaco, Tex.*

Sweet corn as a commercial crop in the Lower Rio Grande Valley is relatively new. It was not until the Iowa hybrid sweet corn, Ioana (I45 x P39) was introduced to this area by this station that it was possible to raise sweet corn for market. Many problems relating to the raising of sweet corn are yet to be dealt with, including those of spacing. It was the purpose of this experiment to study as carefully as possible the relationships between differential spacing in the row and the number of seeds per hill.

Methods

The experiment was laid out as a lattice square with four replications. Spacings were started at 12 inches and increased at 8-inch intervals up to 36 inches. Seeds were planted at the rate of one, two, three, and four seed per hill. Plats were three rows, 3 feet apart by 30 feet long, and only the middle row was harvested as a test row.

There was no increase in precision due to the use of the lattice square design over the randomized block design and the randomized block design was used for testing significance.

The variety of corn used was Ioana produced by the Associated Seed Company of New Haven, Connecticut. This is mentioned because there appears to be some slight difference in the performance of Ioana from different sources. Such differences have not been checked for significance.

Results

The effect of planting rate on yields is not directly concerned with ultimate stand. For this reason, stand is not considered in this part of the experiment. Table I gives the results as obtained from the field notes, and Table II, the variance analysis.

Covariance analysis indicated very little effect of number of seeds planted per hill on yield and a regression curve of yield on stand was developed. This curve was best represented by the exponential equation $y = .6406 + .5161x - .0096x^2$ where y equals yield and x equals stand per plat. According to this equation the maximum yield for Ioana sweet corn was obtained at a stand of 27,000 plants per acre. However, it is not always desirable to produce a maximum yield because there may be too many ears that are too small for market purposes.

Two other regression curves were drawn to show the relationship between rate of seeding and yield, and spacing and yield. The first of these is represented by the equation $y = 1.9875 + 7.0965x - 1.2535x^2$ which indicates that maximum yields are obtained when seed are planted at the rate of three kernels per hill. The second of these equa-

TABLE I—YIELD PER PLAT OF GREEN CORN (POUNDS)

Number of Kernels Per Hill			
1	2	3	4
12-Inch Spacing			
19.12	14.88	15.25	11.50
14.25	10.18	15.51	17.50
5.44	8 62	11.00	10.88
11.00	18.00	15.25	10.75
Total 49.81	51.68	57.01	50.63
20-Inch Spacing			
8.00	14.50	11.31	9.88
11.25	12.50	19.31	12.50
5.50	10.25	15.00	15.75
10.50	9.31	12.50	8.75
Total 35.25	46.56	58.12	46.88
28-Inch Spacing			
9.88	13.50	15.75	10.50
2.12	5.44	13.06	12.75
4.00	7.69	5.75	5.25
5.69	8.06	9.25	5.25
Total 21.69	34.69	43.81	33.75
36-Inch Spacing			
7.31	9.06	7.00	4.62
5.00	4.62	16.62	10.25
4.50	7.12	11.25	7.25
7.00	9.25	13.75	6.94
Total 23.81	30.05	48.62	29.06

TABLE II—ANALYSIS OF VARIANCE

Source of Variance	df	Sum Sq	Mean Sq
Total	63	1,305	——
Seed rate	3	253	84.33*
Spacing	3	234	78.00*
Blocks	3	470	——
Kernels × spacing	13	22	n.s.
Error	33	326	9.88
*.01 point			

Least sig. total difference 18.16 pounds per treatment
Least sig. mean treatment difference 4.54

TABLE III—AVERAGE YIELD AT DIFFERENT SPACINGS AND SEEDING RATES

Spacing Between Hills (Inches)	Pounds Per Plat	No. Kernels Per Hill	Pounds Per Plat
12	13.07	1	8.16
20	11.68	2	10.19
28	8.37	3	12.98
36	8.22	4	10.01

tions is $y = 16.976 - 3.8685x + .4075x^2$. This equation shows that maximum yields were obtained when the closest spacing (1 x 3 feet) was used.

In order to estimate the effect of stand on ear size a similar regression curve for ear size on stand was developed. This curve was best represented by the formula $y = .3459 + .005612x - .000103x^2$. Maximum ear size was obtained at a stand level equivalent to 13,200 plants per acre. A study of the curve indicates however that satisfactory ear

size may be obtained at stand levels as high as 22,000 plants per acre which is equivalent to one plant every 8 inches of lineal 3-foot row.

Observation of the field seemed to indicate that better stands — that is more nearly perfect stands — were obtained when more than one seed was planted per hill. This proved to be faulty observation, for a comparison of stands obtained with the theoretically perfect stands proved that more nearly perfect stands are obtained with single kernel units than with multiple kernel units. There was a consistent decrease in the ratio of kernels planted to stand as indicated by the following:

$S = 1.39 - .27x + .028x^2$ The effect of number of kernels (x) per hill

$S = .5075 + .1035x - .0125x^2$ The effect of spacing (x)

When S equals expected stand.

A study of the individual hill stand data, shown in Table IV will further indicate the effects of planting distance and planting rate on ultimate stand.

TABLE IV—Number of Mature Stalks Per Plat Expressed as Per Cent of the Number of Seeds Planted

Spacing	Kernels Per Hill				Average
	1	2	3	4	
12	71	56	55	57	60
20	89	67	59	47	66
28	100	72	62	51	71
36	100	78	66	45	72
Average	90	68	60	50	67

Discussion

From the results obtained it appears that yield differences due to spacing are almost entirely due to the stand obtained and not to method of planting. In other words, when the number of plants per lineal foot of row is the same, yields at the same level may be expected to be nearly the same whether one, two, three, or four kernels per hill are used. From the standpoint of the production of sweet corn in this area it is apparent that it will not be advisable or necessary to use hill planting to get the best results.

Stand has a marked effect on ear size. If stands are too heavy, yields of marketable corn will be reduced because of small ear size, even though total yields may be somewhat increased by closer planting. Apparently, sweet corn should be maintained at stand levels of about 22,000 plants per acre which is equivalent to one plant every 8 inches of row or one plant for each two square feet of area. Excellent yield may be expected from somewhat wider spacing, say one plant per 3 square feet of area.

From the standpoint of seeding efficiency, the single seed drop method is superior to the hill method and probably should be used for this crop.

Summary

Under the 1944 spring growing conditions in the Lower Rio Grande Valley, it was found that method of planting had little effect on the total yield of sweet corn. It was found that rate of planting greatly influenced total yield and ear size and that all things considered, a spacing of 2 square feet per plant produced the maximum yield of marketable corn per acre.

It was found that the most efficient use of seed was obtained with the maximum spacing (3 x 3 feet), using one kernel per hill. From the standpoint of production, however, it would be an error to consider the matter of seeding efficiency of any importance. Maximum yields were made at seeding efficiencies of 55 to 66 per cent.

Further Studies on Effect of Temperature on Initiation of Flowering in Celery[1]

By H. C. THOMPSON, *Cornell University, Ithaca, N. Y.*

THE writer (1, 2) has shown that celery plants grown for short periods at relatively low temperatures (40 to 50 degrees, or 50 to 60 degrees F) will go to seed subsequently at temperatures too high for the initiation of the reproductive phase. In order to determine whether or not breaking the cold treatment, by alternately subjecting the plants to relatively low, and medium, or high temperature would interfere with floral induction three experiments were conducted in 1943 and 1944. The same stock of seed of Cornell 6 was used in all three experiments. This is a pure line somewhat susceptible to early seeding. Since the three experiments were conducted somewhat differently they are discussed separately.

EFFECT OF TEMPERATURE TREATMENTS IN GREENHOUSE ON SUBSEQUENT DEVELOPMENT OF SEEDSTALK IN THE FIELD

Seed for this experiment was sown in a medium temperature greenhouse (60 to 70 degrees F) December 6, 1942 and the seedlings were pricked out 2 x 2 inches apart into flats January 8, 1943. The temperature treatments were started March 2 and were continued for 15 or 30 days as shown in Table I. As soon as the treatments were completed the plants were returned to the 60 to 70 degrees F greenhouse where they remained until set in the field. All plants used in the experiment were potted in 4-inch pots on April 2. The plants were set in the field May 7, about 7 inches apart in the row with the rows 3 feet apart. There were 48 plants in each treatment and these were divided into two lots of 24 plants each. The soil, a sandy-loam, was manured and fertilized with 1500 pounds of 5–10–5 fertilizer per acre. The results of this experiment are given in Table I.

TABLE I—EFFECT OF TEMPERATURE TREATMENTS IN GREENHOUSE ON SUBSEQUENT DEVELOPMENT OF SEEDSTALKS IN THE FIELD

No.	Temperature Treatment Prior to Field Planting (Degrees F)	Per Cent Seedstalks on Dates Given		
		June 22	Jul 6	Jul 14
1	Check, 60 to 70 degrees	0.00	0.00	0.00
2	50 to 60 degrees for 30 days	91.67	100.00	100.00
3	50 to 60 degrees for 15 days	43.75	58.33	66.67
4	40 to 50 degrees for 30 days	100.00	100.00	100.00
5	40 to 50 degrees for 15 days	100.00	100.00	100.00
6	Alternating 50 to 60 degrees and 60 to 70 at 24-hour intervals for 30 days	31.25	50.00	62.50
7	Alternating 40 to 50 degrees and 60 to 70 at 24-hour intervals for 30 days	100.00	100.00	100.00

[1]Paper No. 269. Department of Vegetable Crops, Cornell University, Ithaca, New York.

The data in Table I show that the plants grown in the 60 to 70 degrees F greenhouse until they were set in the field produced no seedstalks. All of the plants that were grown for 15 and 30 days at 40 to 50 degrees F and all of those grown for 30 days at 50 to 60 degrees went to seed. Fifteen days at 50 to 60 degrees resulted in two-thirds of the plants producing seedstalks. Growing the plants alternately at 40 to 50 degrees and 60 to 70 degrees at 24-hour intervals for 30 days had the same effect as growing them for 15 days continuously at 40 to 50 degrees. Likewise alternating between 50 to 60 degrees and 60 to 70 degrees for 30 days had essentially the same effect as 15 days continuously at 50 to 60 degrees.

Effect of Temperature Treatments Given in Constant-Temperature Rooms on Subsequent Development of Seedstalks in the Field[2]

Plants for this experiment were grown from December 6, 1942 to March 2, 1943, in the same greenhouse and in exactly the same way as in the experiment previously described. On March 2 these plants were potted in 4-inch pots and placed in a greenhouse belonging to the U. S. Regional Soil, Plant, and Nutrition Laboratory where they were kept for 17 days. No record was kept of the temperature of this greenhouse for the 17-day period. Temperature treatments began March 19 and ended April 19 and during the treatment period for each lot, the plants were grown in constant-temperature rooms under artificial light for 16 hours, from 4 p. m. until 8 a. m. The light was supplied half from white tubes and half from daylight tubes, and the intensity varied from 800 to 1000 foot candles.

After the temperature treatments were concluded the plants were returned to the 60 to 70 degrees greenhouse and were kept there until they were set in the field May 7, 1943. The number of plants were 14 in treatments 1 to 8, 20 in treatments 9 to 13, and 28 in treatment 14. The plants in this experiment were grown in the field under the same conditions as those in the previous experiment. The treatments given and the results are shown in Table II.

The data in Table II show that all the plants subjected to 50 degrees F for 8, 12, 16 and 20 days and at 65 degrees for 22, 18, 14 and 10 days went to seed subsequently in the field. Growing the plants for 10 days at 75 degrees immediately after the low-temperature treatment for 8, 12, 16 and 20 days did not nullify the effect of the previous low temperature, although 2 of the 14 plants grown at 50 degrees for 8 days did not develop seedstalks. Breaking the cold treatment, by subjecting the plants alternately to 65 and 50 degrees for 30 days did not nullify the effect of the cold treatment, regardless of whether the plants were subjected to the cold during the light period, or the dark period. Seedstalk development of 70 per cent of the

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[2]The writer wishes to thank Dr. K. C. Hamner of the U. S. Regional Soil, Plant, and Nutrition Laboratory for his cooperation in providing the constant-temperature rooms, for caring for the plants during the time they were given the treatments, and for his helpful suggestions and advice.

TABLE II—EFFECT OF TEMPERATURE TREATMENTS IN CONSTANT-TEMPERATURE ROOMS ON SUBSEQUENT SEEDSTALK DEVELOPMENT IN THE FIELD

No.	Temperature Treatment Prior to Field Planting (Degrees F)	Per Cent Seedstalks on Dates Given		
		June 22	Jul 6	Jul 14
1	50 degrees 8 days, 65 degrees 22 days.	100.00	100.00	100.00
2	50 degrees 12 days, 65 degrees 18 days	100.00	100.00	100.00
3	50 degrees 16 days, 65 degrees 14 days.	100.00	100.00	100.00
4	50 degrees 20 days, 65 degrees 10 days	100.00	100.00	100.00
5	50 degrees 8 days, 75 degrees 10 days	35.71	85.71	85.71
6	50 degrees 12 days, 75 degrees 10 days.	85.71	92.86	100.00
7	50 degrees 16 days, 75 degrees 10 days	78.57	100.00	100.00
8	50 degrees 20 days, 75 degrees 10 days	92.86	100.00	100.00
9	65 degrees 16 hours light and 50 degrees 8 hours dark daily for 30 days.	65.00	80.00	80.00
10	50 degrees 16 hours light and 65 degrees 8 hours dark daily for 30 days	25.00	100.00	100.00
11	Alternate days 65 and 50 degrees for 30 days.	30.00	100.00	100.00
12	50 degrees for 30 days	100.00	100.00	100.00
13	65 degrees for 30 days.	25.00	60.00	70.00
14	75 degrees for 30 days	0 00	0.00	0.00

plants that were grown for 30 days at 65 degrees is at variance with the results of the other two experiments reported in this paper and of results of earlier experiments previously reported by the writer. A mistake might have been made either in the treatment or in the labeling in the field. It is possible that the temperature in the greenhouse where the plants were kept from March 2 to 19 was not above 60 degrees all of the time. No record was kept of the temperature in this house. Plants that had no low temperature treatment but were grown at 75 degrees for 30 days produced no seedstalks in the field.

EFFECT OF TEMPERATURE AND LENGTH OF PHOTOPERIOD ON SUBSEQUENT DEVELOPMENT OF SEEDSTALK IN A MEDIUM TEMPERATURE (60 TO 70 DEGREES F) GREENHOUSE 1943–44

Results of the previous experiment showed that 8 days exposure to 50 degrees F resulted in 100 per cent of the plants developing seedstalks in the field. It seemed desirable to determine whether or not a shorter cold treatment would be effective and to answer the question an experiment was set up in the autumn of 1943.

Seed for this experiment was sown in the greenhouse August 24, 1943 and the seedlings were transplanted 2 x 2 inches apart in flats September 27. The plants were kept in a greenhouse held at 60 to 70 degrees F (except in the early autumn when the outside temperature was too high) until the treatments started on November 11. The temperatures to which the plants were subjected during the preliminary treatment and the length of treatment are shown in Table III. All of the plants were kept in a greenhouse at 60 to 70 degrees except for the periods shown. After the temperature treatments the plants were potted in 4-inch pots and the 40 plants in each treatment were divided into two lots of 20 plants each. One set was grown under the normal length of day from December 13 to the end of the experiment

April 18 and the other set was grown under 15 hours of light. Artificial light was supplied by 100-watt Mazda bulbs 3 feet above the plants, spaced 3 feet apart over the center of a bench 3 feet wide. The lights were turned on a little before sundown and turned off at such time as would give 15 hours of light (daylight plus from 2½ to 5½ hours of artificial light.) The results of this experiment are shown in Table III.

TABLE III—EFFECT OF TEMPERATURE AND LENGTH OF PHOTOPERIOD ON SUBSEQUENT DEVELOPMENT OF THE SEEDSTALK IN THE GREENHOUSE 1943–44

	Preliminary Temperature Treatment (Degrees F)	Per Cent of Seed stalks on Dates Given							
		Mar 12		Mar 26		Apr 9		Apr 18	
		A	B	A	B	A	B	A	B
1	Check (60 to 70 degrees)	0	0	0	0	0	0	15	0
2	40 to 50 degrees 2 days.	0	0	0	0	0	5	55	5
3	40 to 50 degrees 4 days	0	0	0	0	15	35	75	65
4	40 to 50 degrees 8 days	0	5	15	20	60	75	90	80
5	40 to 50 degrees 16 days	35	60	75	95	95	100	100	100
6	40 to 50 degrees 32 days	70	95	100	100	100	100	100	100
7	40 to 50 degrees 3 days, 60 to 70 degrees 1 day	0	0	0	5	10	20	85	75
8	Alternating 40 to 50 degrees and 60 to 70 degrees at 24-hour intervals for 8 days	0	0	0	10	40	30	70	65
9	Same treatment as 7 for 16 days	0	5	0	15	55	65	90	85
10	Same treatment as 7 for 32 days	0	50	40	85	100	100	100	100
11	Alternating 40 to 50 degrees and 60 to 70 degrees 12-hour intervals, 4 days-night 40 to 50 degrees	0	0	0	0	5	15	85	60
12	Same treatment as 11 for 8 days.	0	0	0	0	5	20	85	50
13	Same treatment as 11 for 16 days	0	15	0	60	40	85	100	95
14	Same treatment as 11 for 32 days	0	15	25	85	80	100	100	100
15	Alternating 40 to 50 degrees and 60 to 70 degrees 12-hour interval 8 days—day 40 to 50 degrees	0	15	0	40	15	75	85	95
16	Same treatment as 15 for 16 days.	0	0	0	70	45	90	75	100
17	Same treatment as 15 for 32 days	0	55	0	80	80	95	100	100

A = Plants grown under normal day length Nov. 13 to end of experiment.
B = Plants grown under 15 hours of light Nov. 13 to end of experiment.

While the results shown in Table III are not entirely consistent, they do show that exposing the plants to 40 to 50 degrees F for as little as two days had an appreciable effect on subsequent development of the seedstalks. In general, as the length of the low-temperature treatment was increased the earlier the seedstalks were developed and the higher was the percentage of seeders. Growing the plants alternately at 40 to 50 degrees and 60 to 70 degrees at 24-hour, or 12-hour intervals had essentially the same effect as growing them for half as many days at 40 to 50 degrees. When the plants were given the alternating treatment at 12-hour intervals the results were essentially the same when the cold treatment was given during the day as when it was given during the night.

Plants grown under 15 hours of light made much greater growth and produced seedstalks slightly earlier than those grown under the normal length of day. However, at the end of the experiment there was a slightly higher percentage of seeding in the plants grown under the normal length of day (83 per cent) than in those grown under the 15-hour day (75 per cent).

Effect of Temperature and Length of Photoperiod on Subsequent Development of Seedstalk in a Warm Greenhouse, 1943–44

In order to determine the effect of relatively high temperature on seedstalk development following the cool-temperature treatment 40 plants each of five treatments were grown from December 13 to April 18 in a greenhouse held between 70 and 80 degrees F. The treatments were check (60 to 70 degrees); 16 days at 40 to 50 degrees; 32 days at 40 to 50 degrees; alternating between 40 to 50 degrees and 60 to 70 degrees at 24-hour intervals for 16 days and alternating between these temperatures for 32 days. After the temperature treatments the 40 plants from each treatment were divided into two lots of 20 plants each. One lot was grown under the normal length of day and the other 15 hours of light as described in the preceding section.

At the conclusion of the experiment April 18, not a seedstalk had developed regardless of the previous treatment. Three lots of plants given the same preliminary low-temperature treatments and grown subsequently in the 60 to 70 degrees F greenhouse under the normal length of day produced 100 per cent and a fourth lot produced 90 per cent seedstalks. This indicates that the relatively high temperature nullified the effect of the low-temperature treatment and prevented the development of the flower primordia, although induction undoubtedly had taken place. Careful examination of the plants showed no evidence of flower primordia. These results are in line with those previously reported by the writer (2).

Summary

Results of three experiments reported may be summarized as follows:

Growing celery plants for as short a period as 2 days at 40 to 50 degrees F had an appreciable effect on seedstalk development when the plants were grown subsequently at temperatures too high for floral induction. Four days at 40 to 50 degrees resulted in 75 per cent of the plants going to seed subsequently at 60 to 70 degrees under the normal length of day from December 13 to April 18.

Growing the plants alternately at 40 to 50 and 60 to 70 degrees F had essentially the same effect on subsequent seeding as growing them for half as long a period at 40 to 50 degrees F. This was true regardless of whether the intervals were of 12 or 24 hours duration and whether the plants were held at low temperature during the dark or light period. In other words, breaking the cold treatment, by alternating between low and medium or high temperature, did not nullify the effect of the low-temperature treatment. This is in contrast to the results obtained by Garner and Allard (3 and 4) and by Hamner (5) in studies of the effect of breaking the light and dark periods on the response of certain plants to photoperiod.

When plants were grown in a warm greenhouse (70 to 80 degrees F) after the low-temperature treatment no seedstalks were formed

regardless of the length of the cold treatment up to 32 days. This high temperature seems to prevent floral initiation although induction must have taken place.

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Germination of Lettuce Seed at High Temperature (25 to 35 Degrees C) Stimulated by Thiourea

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That certain sulphur-nitrogen compounds, including thiourea, allyl thiourea, thio-semicarbamide, thioacetamide, ammonium thiocyanate, and postassium thiocyanate have a stimulating effect on the germination of dormant lettuce seed was shown by Thompson and Kosar (8). Of the sulphur-nitrogen compounds used, thiourea was found to be the most effective in promoting germination and to be the most consistent in its effects.

Since the publication of above-mentioned data, thiourea has been used by the senior author to stimulate germination of many lots of lettuce seed found to be difficult to germinate under ordinary conditions without treatment.

From the data accumulated on the influence of thiourea on the germination of lettuce seed it appeared that the thiourea treatment often increased the percentage of germination of lettuce seed at unfavorably high temperatures (above 25 degrees C).

Tests have been made on numerous lots of lettuce seed to determine if the observed tendency for the thiourea treatment to stimulate germination of lettuce seed at temperatures above 25 degrees is consistent and of sufficient importance to be of practical value. The present paper is a presentation of some of the results obtained from these tests.

Experimental Tests

Series 1:—For the first series of tests, seed of 10 unnamed breeding stocks were selected at random from a large number of stocks available. These were first tested for germination at 18, 27, 30, and 34 degrees C in quintuplicate lots of 25 seed each. The seeds were placed on wet filter paper in Petri dishes in a germinator. The germination counts were made at the end of 72 hours. These germination tests were made to determine the temperature at which these particular lots of seed begin to decline in their percentage of germination. The results are given in Table I. All 10 lots gave practically 100 per cent germination at 18 and 27 degrees. At 30 degrees the germination of all but three lots dropped to a very low percentage. Germination failed almost completely in all lots at 34 degrees. All of these 10 lots of seed were capable of germinating at a temperature well above the average for many lots of commercial lettuce seed. Germination is often poor at temperatures even below 25 degrees.

The temperatures used for treating and germination throughout these investigations were employed largely because chambers controlled at these temperatures were available for use. In some cases other temperatures might have been more desirable. However, it was concluded that satisfactory information could be obtained more economically by utilizing already available equipment rather than by setting up new controls.

TABLE I—SUMMARY OF DATA ON 10 STRAINS OF LETTUCE SEED GERMINATED AT 18, 27, 30, AND 34 DEGREES C. COUNTS MADE AT END OF 72 HOURS; FIVE LOTS OF 25 SEED FOR EACH TREATMENT

Strain No.	Total Germination At				Grand Total
	18 Degrees C	27 Degrees C	30 Degrees C	34 Degrees C	
1541-1	125	122	1	0	248
1562-4	125	125	5	0	255
1562-8	124	125	17	0	266
1568-2	125	124	114	0	363
1592-12	125	125	37	0	287
1620-7	124	125	23	1	273
1624-4	123	125	119	8	375
1624-9	125	125	100	1	351
1640-4	124	123	20	1	268
1664-1	125	125	8	0	258
Totals	1,245	1,244	444	11	2,944
Per cent	99.6	99.5	35.3	0.9	—

Series 2:—In order to test the effectiveness of various treatments in promoting germination at high temperatures (above 25 degrees), portions of each of the 10 seed stocks used in series 1 were treated as follows:

1. Soaked in 0.5 per cent thiourea solution, in a Petri dish in darkness for 4 hours at a constant temperature of 18 degrees C.
2. Same as 1 except that the soaking period was for 7 hours.
3. Same as 1 except that the soaking period was for 12 hours.
4. Soaked in 0.5 per cent thiourea solution in a Petri dish in darkness for 4 hours at a constant temperature of 27 degrees C.
5. Same as 4 except that the soaking period was for 7 hours.
6. Same as 4 except that the soaking period was for 12 hours.
7. Soaked in 0.5 per cent thiourea solution in a Petri dish in diffused light for 7 hours at room temperature of 10 to 15 degrees C.
8. Soaked in 0.5 per cent thiourea solution in a Petri dish in diffused light for 7 hours at room temperature of 20 to 25 degrees C.

9 to 16, inclusive. These treatments were duplicates of 1 to 8, respectively, except that tap water was used for soaking in place of the thiourea solution.

Thompson and Kosar (8) have determined the optimum concentration of thiourea solution for the stimulation of germination in lettuce seed to be approximately 0.5 per cent, and this concentration was used throughout these tests.

At the conclusion of each soaking period the thiourea-treated seeds were washed in tap water to remove the thiourea from the surface of the seed but not to leach it out of them. The seeds were then placed on absorbent paper and dried thoroughly. The seeds were scattered on the paper thinly so that their surface would dry quickly. The water-treated samples were dried in the same manner at the end of the treatment period. After thoroughly drying, the treated seeds were placed in brown paper envelopes and stored for 10 days to 2 weeks at room temperature of 15 to 25 degrees C. A 10-day period was considered

to be sufficiently long for practical use of the procedure in treating lettuce seed for field planting.

After 10 days or more in storage, the 16 treated samples and an untreated check for each of the 10 seed stocks were tested for germination. The germination tests were made in water in Petri dishes with a filter paper in both top and bottom of each dish. Five dishes with 25 seeds each were used for each treatment of each lot (850 dishes). The germinator was held at 33 to 35 degrees, this extremely high germination temperature being used in order to approach the most severe conditions of temperature that might be encountered under field conditions in mid-summer.

Results

The results obtained in series 2 are presented in Table II. The same set of checks was used for both the thiourea and the tap water subseries. The figures in all columns except the totals represent the germination in 5 dishes with 25 seeds each.

TABLE II—Summary of Data on 10 Strains of Lettuce Seed Germinated at 33 to 35 Degrees C After Various Treatments, as Indicated. Counts Made at the End of 72 Hours; Five Lots of 25 Seed of Each Strain for Each Treatment

Treatment and Strain No.	Light Relation								Total	Untreated Check
	Darkness						Diffused Light			
	18 Degrees C			27 Degrees C			10 to 15 Degrees C	20 to 25 Degrees C		
	4 Hours	7 Hours	12 Hours	4 Hours	7 Hours	12 Hours	7 Hours	7 Hours		
	Thiourea									
1541-1	11	107	109	4	86	112	72	26	527	0
1562-4	24	115	114	37	73	111	66	10	550	0
1562-8	65	118	99	68	104	111	88	76	729	0
1568-2	109	124	124	112	125	121	117	111	943	0
1592-12	44	122	122	74	123	125	101	73	784	0
1620-7	25	91	81	13	38	24	15	15	302	1
1624-4	71	125	123	98	123	119	114	85	858	8
1624-9	100	123	120	92	121	116	117	96	885	1
1640-4	43	97	104	48	76	115	45	46	574	1
1664-1	13	68	70	15	9	29	5	13	222	0
Total ..	505	1,090	1,066	561	878	983	740	551	6,374	11
Percentage	40.4	87.2	85.3	44.9	71.0	78.6	59.2	44.1	63.7	0.9
	Tapwater									
1541-1	2	46	17	3	0	75	20	6	169	0
1562-4	28	60	36	9	10	79	15	23	260	0
1562-8	79	89	75	33	19	106	46	65	512	0
1568-2	107	121	113	99	50	108	94	99	791	0
1592-12	51	108	81	42	11	110	73	71	547	0
1620-7	18	67	25	10	18	1	3	29	171	1
1624-4	74	104	83	77	56	83	65	72	614	8
1624-9	93	115	92	76	57	75	101	79	688	1
1640-4	36	52	41	24	4	65	25	32	279	1
1664-1	7	30	7	12	2	2	3	16	79	0
Total...	495	792	570	385	227	704	445	492	4,110	11
Percentage...	39.6	63.4	45.6	30.8	18.2	56.3	35.6	39.4	41.1	0.9

Water Treatments

It has been shown by Hopkins (3), Larson, Gilbert, and Ure (4), Shuck (5), and Thompson (7) that soaking lettuce seed in water prior to germination has a beneficial influence. The water treatments were included in the present tests in order to take account of the influence of water in the thiourea solution.

The data in Table II show that water alone had a very marked stimulating effect on germination of lettuce seed at unfavorably high temperatures under certain conditions of treatment, and that there is some beneficial effect under nearly all of the conditions studied.

A study of the data in Table II indicates that water treatments carried out at a temperature of 18 degrees are more effective than similar treatments at 27 degrees.

There are some inconsistent results in the data for the various durations of treatment. The total germination for the 7-hour, 27-degree C, tap water treatment in darkness seems to be too low; however, there is no obvious explanation for the discrepancy. The poor germination under this treatment was consistent for the 10 lots of seed. The 4-hour treatment is obviously too short for maximum effect at the temperatures used. In some seed samples the 12-hour treatment gave good germination, especially at 27 degrees. However, many of the embryos showed injury on germination when thus treated for 12 hours; injury was also observed, but in less degrees, in embryos germinated from the 12-hour, 18-degree treatments.

The highest percentage of germination for water treatments, without injury to at least some embryos, was obtained from the 7-hour, 18-degree C treatment.

Seed samples treated at low temperature (10 to 15 degrees C) and higher temperature (20 to 25 degrees C) for 7 hours in diffused light failed to give as good results as the 7-hour, 18-degree treatment in darkness.

Thiourea Treatments

The results for the thiourea treatments closely parallel those for the water treatments, but in every case the average percentage of germination was higher in the thiourea-treated samples, and in most instances it was very much higher. The average germination of all thiourea-treated samples was 63.7 per cent; of all water-treated samples, 41.1 per cent; of the untreated checks, 0.9 per cent. The superiority of the thiourea treatment is also shown when the germination figure for the most favorable thiourea treatment (7-hour, 18-degree C) is compared with the most favorable water treatment (7-hour, 18-degree). The thiourea treatment gave 87.2 per cent and the water treatment 63.4 per cent.

As in the water treatments, the 4-hour period is too short for maximum effect and injury occurs when the treating period is increased to 12 hours. The 18-degree C temperature was more effective than the 27-degree temperature, as was true of the water treatment.

Exposure of the soaking seed to diffused light reduced the beneficial effect below that of similar treatments in darkness.

Series 3:—To further test the effectiveness of the thiourea treatment, a third series of tests was conducted in which seeds of 10 named lettuce varieties were used. In this series the samples were given the treatment found in series 2 to be the most effective in promoting germination of lettuce seed at high temperature, that is, in darkness for 7 hours at 18 degrees C. The samples were washed and dried as described in series 2 and stored at 10 degrees for 3 weeks.

At the end of the 3 weeks' storage period the treated and untreated samples of the same seed stocks were tested for germination in quintuplicate lots of 25 seeds each at 32 to 34 degrees C.

Results

The results from series 3 are given in Table III. The average germination for the 10 thiourea-treated samples was 87.3 per cent and for the 10 untreated samples 0.6 per cent. It is purely coincidental that the percentage of germination for the thiourea-treated samples in series 3 was almost identical with the percentage of germination for the wholly different samples in series 2 which were given the same treatment (87.3 and 87.2 per cent, respectively).

TABLE III—Summary of Data on Germination at 32 to 34 Degrees C of 10 Varieties of Lettuce Seed Stored for 3 Weeks at 10 Degrees C After Treatment with 0.5 Per Cent Thiourea in Darkness for 7 Hours at 20 Degrees C. Counts Were Made at the End of 72 Hours

Variety	Thiourea Replications (25 Seeds Each)						Untreated Replications (25 Seeds Each)					
	1	2	3	4	5	Total	1	2	3	4	5	Total
Black Seeded Simpson	25	24	24	25	24	122	0	1	0	2	0	3
Hansonette	24	23	25	23	24	119	0	0	2	0	0	2
Imperial 44	24	25	22	21	23	115	1	0	0	0	0	1
Tomhannock	22	23	25	19	25	114	0	0	0	0	0	0
Cosbia	20	22	23	25	23	113	0	0	0	0	0	0
Great Lakes	24	17	25	24	22	112	0	0	0	0	1	1
Dark Green Cos	25	20	23	21	18	107	0	0	0	0	0	0
Paris White Cos	21	19	18	22	19	99	0	0	0	0	0	0
Arctic King	24	16	19	17	23	99	0	0	0	0	0	0
Green Mediera Winter	16	20	19	20	17	92	0	0	0	0	0	0
Total	—	—	—	—	—	1,092	–	–	–		–	7
Percentage	—	—	—	—	—	87.3	–	–	–	–	–	0.6

Series 4:—A fourth series of tests was made to study the influence of storage temperature on the viability and germination capacity of thiourea- and water-treated lettuce seed.

Ten breeding stocks not peviously used in these tests were selected. Each of the 10 samples was divided in two equal portions. One-half of each lot was treated with 0.5 per cent thiourea solution in darkness for 7 hours at 18 degrees C. The other half was given similar treatment except that tap water was used in place of the thiourea solution. Each sample was washed and dried following treatment, as described for series 2. After a few days a portion of each of the treated samples and an untreated check for each were tested for germination at 32 to 34 degrees. The remainder of each treated sample was then divided

into two approximately equal parts. A half of each sample was stored in darkness at 10 to 12 degrees and the other half in darkness at 20 to 30 degrees. After 2 months in storage all of the treated samples from both storage conditions and untreated checks for each seed stock were tested for germination in quintuplicate lots of 25 seeds each in a germinator at 32 to 34 degrees.

Results

The results from the tests in series 4 are presented in Table IV. The 10 thiourea-treated and 10 water-treated samples gave average germination of 89.2 and 53.2, respectively, when tested a few days following treatment. The portions of these same treated samples stored for 2 months at 10 to 12 degrees C gave an average germination of 88.9 per cent for the thiourea-treated and 51.8 per cent for the water-treated. The portions of the treated samples stored for 2 months at 20 to 30 degrees gave 82.6 per cent for the thiourea-treated and 42.4 for the water-treated.

TABLE IV—Summary of Data on the Influence of Storage Temperature Following Treatment on the Germination of 10 Strains of Lettuce Seed at 32 to 34 Degrees C. Counts Made at the End of 72 Hours; Five Lots of 25 Seed of Each Strain for Each Treatment

Treatment	Storage After Treatment	Number Seed Germinating Out of 1,250	Average Per Cent Germinated
Thiourea in darkness at 18 degrees for 7 hours	Not stored	1,115	89.2
	2 months, 10 to 12 degrees C	1,111	88.9
	2 months, 20 to 30 degrees C	1,033	82.6
Water in darkness at 18 degrees for 7 hours	Not stored	665	53.2
	2 months, 10 to 12 degrees C	647	51.8
	2 months, 20 to 30 degrees C	530	42.4
Untreated check. .. .	10 to 12 degrees C	15	1.2

The decline in percentage of germination of both thiourea- and water-treated samples during 2 months in storage at 10 to 12 degrees C was insignificant. However, the decline of 6.6 in percentage for thiourea-treated and 10.8 in percentage for water-treated seed stored at 20 to 30 degrees for 2 months is significant and indicates that treated seed if stored should be held at a relatively low temperature in order to preserve its viability and retain its power to germinate readily.

Discussion

The data accumulated from these tests indicate that thiourea at the low concentration of 0.5 per cent is highly effective in promoting germination of lettuce seed at temperatures between 25 and 35 degrees C. They show that tap water may also be effective in promoting germination of lettuce seed at such temperatures. However, thiourea-treated lots always gave a higher percentage of germination than water-treated lots of the same strain or variety.

In treating lettuce seed to promote its germination at unfavorably high temperatures, whether with thiourea or with water, it is important that several factors pertaining to the treatment be standardized and controlled. These are light, temperature, and duration.

The studies made by Hopkins (3), Larson, Gilbert, and Ure (4), Shuck (5), and Thompson (7) indicated the stimulating effect on the germination of lettuce seed induced by presoaking in water. However, these earlier investigations failed to establish the importance of the duration of the treatment and the effect of drying following treating in producing the maximum stimulation. The recommended procedure for presoaking of lettuce seed in water to promote germination has been to presoak for about 2 hours. The results of the present studies indicate that maximum stimulation can not be obtained unless the soaking period is extended to 8 to 10 hours, where the seed is to be dried and kept for some time before it is germinated. The time requirement for soaking may be different where the seed is to be germinated at once without drying. In the present investigations, no study was made of the requirement for presoaking, as used in laboratory practice where the seeds are not dried. The drying is a very important step in the method outlined in this paper. Under certain conditions of temperature, a treating period of more than 10 hours may result in a slightly higher percentage of germination than is obtained at 8 to 10 hours. However, a longer soaking period may result in serious injury to some embryos, and a poorer stand of plants may result than if the treating period is of slightly shorter duration.

A higher percentage of germination and more normal embryos were obtained when the treating was done at 18 degrees C than when at 27 degrees.

Flint (1), Flint and McAlister (2), and Shuck (6) have shown that exposure of lettuce seeds to certain rays of light during germination or while the seeds are in a moist condition prior to germination has a stimulating effect on their germination. In the present investigations, seeds exposed to diffused sunlight during the treating period at both high (20 to 25 degrees C) and at low (10 to 15 degrees) temperature failed to germinate as well as samples treated under similar conditions in the absence of light.

The results obtained from tests in series 4 indicate that the stimulating effect of the thiourea and the water treatments on the germination of lettuce seed may remain for a period of 2 months and probably longer, if the seed is properly dried following the treatment and stored at low temperature. This would permit lettuce seed to be treated in bulk well in advance of the planting season, and stored until the planting date.

The treating of large quantities of seed may introduce some problems not studied in the investigations reported here. For example, the treating of large quantities of seed may introduce the factor of aeration during treatment. The small samples used in the tests reported here presented no problem of aeration since the seeds were in every case spread rather thinly over the bottom of the Petri dishes, permitting fairly good aeration of all the seeds in the dish. When

large quantities are treated, the seed at the bottom and at the center of the mass would be poorly aerated unless special equipment is used whereby the seeds could be constantly agitated. The possible necessity for aeration during the treating process is purely hypothetical since we have no experimental evidence at present indicating the need for aeration. The problem of aeration is raised here merely to point out the fact that all phases of the treatment have not yet been investigated and to warn against applying the treatment under conditions widely different from those studied thus far.

Another problem that may arise in the treatment of large quantities of seed is in connection with the method to be employed in drying the seed following treating. The drying of large volumes of seed may present some difficulties. It is quite necessary that the seed be dried quickly at the end of the treating period. Holding the seed in a wet condition is in reality extending the treating period and this must be avoided, especially if the seed is treated for longer than 10 hours.

Summary

Numerous genetically different lots of lettuce seed were treated with 0.5 per cent solution of thiourea under several conditions of temperature, time, and exposure to light. In every case thiourea-treated seed gave a much higher percentage of germination at temperatures above 30 degrees C than did untreated seed.

Many of the same lots of seed were treated by soaking in water under the same conditions as for the thiourea solution. In most cases a very marked stimulating effect on germination at temperatures above 30 degrees resulted from the water treatments. However, the thiourea-treated lots always gave a higher percentage of germination than lots treated with water under the same conditions of temperature, time, and exposure to light.

The most effective combination of treatment conditions, with either thiourea solution or water, was found to be a treating period of 8 to 10 hours at 18 degrees C in darkness, the seed being dried off rapidly on removal from the solution.

Treating for as much as 12 hours resulted in injury to some embryos, especially at the higher temperature used (27 degrees C).

Treating the seed in darkness was found to be more effective than treating in diffused sunlight.

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Oil Sprays for the Control of Weeds in Carrots and Other Vegetables (Preliminary Report)[1]

By R. D. Sweet, R. Kunkel, and G. J. Raleigh,
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Controlling weeds in vegetable crops is an important part of successful vegetable production. With small-growing, closely-spaced crops such as carrots and onions, weed control is often the largest single item of production expense. Growers and research workers have long been interested in methods of weed control that are less laborious than hand weeding. A selective weed-killing spray would be considered a distinct improvement over present methods.

Sulfuric acid and Sinox (sodium-dinotro-ortho-cresylate) have been used for weed control in small grains and onions. Iron sulfate, sodium chlorate, ammonium sulfate, ammonium nitrate, borax, and several other materials have been used in controlling weeds in lawns. These materials in general are most effective against plants with broad or easily wettable leaves and are relatively ineffective against grasses.

Kerosene has been reported by Loomis (1936) and Litzenberger and Post (1943) as a selective spray for dandelions in lawns. Stove oil, a western petroleum product similar to kerosene, has been reported as a selective weed killer in carrots by Raynor (not dated) and by Crafts and Reiber (1944).

The purpose of these experiments was to determine: (a) if stove oil would be a satisfactory selective weed killer in carrots under climatic conditions prevailing in New York; (b) if any New York oil product could be substituted for stove oil; (c) if climatic conditions affect the efficiency of oil sprays; (d) if any vegetable crops other than carrots are tolerant of oil sprays; and (e) if any weeds are tolerant of oil sprays.

Methods and Materials

The materials used were stove oil (as used in Arizona), fuel oil No. 2, and kerosene. The latter two oils were obtained from three different sources. The oils were applied undiluted by means of a small knapsack sprayer. The dosage was at a rate sufficient to thoroughly wet the foliage of weeds and carrots. The rate per acre varied by several times depending on weed and crop growth. When weeds were three to four inches tall and very thick, about 150 gallons of oil was applied per acre.

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[1]Paper No. 268. Department of Vegetables Crops, Cornell University, Ithaca, New York.

Acknowledgments: The authors wish to acknowledge their indebtedness to all the growers who cooperated in this work and to the following county agricultural agents and assistants who helped with much of the field work: F. H. Blodgett, W. W. Burger, D. Dalrymple, L. A. Dickerson, L. Freeman, and F. M. Gordon.

Experimental Results

A summary of the results obtained with 18 different crops treated with oils is presented in Table I. It is interesting to note that those vegetable crops exhibiting tolerance to oils are members of the Umbelliferae family. From Table II, however, it can be seen that in weeds tolerance is not restricted to the umbells. Fortunately most of the more troublesome weeds in New York carrot fields are susceptible to oil sprays.

TABLE I—Vegetable Crops and Their Susceptibility to and Tolerance of Oil Sprays

Tolerant	Susceptible	
carrot	beet	onion
celery (partial)	cabbage	pea
celeriac	Chinese cabbage	potato
turnip-rooted parsley	cucumber	snap bean
	kohl-rabi	spinach
	lettuce	sweet corn
	muskmelon	tomato

TABLE II—Weeds and Their Susceptibility to and Tolerance of Oil Sprays

Tolerant		Susceptible	
galensoga	wild carrot	dandelion	red root
poison ivy	grasses*	lamb's quarters	sorrel
ragweed		purslane	grasses*

*Not identified, but most common grasses were susceptible.

The majority of experiments were conducted with carrots. Records were obtained on a total of 19 experiments with this crop in 15 locations throughout New York State during the 1944 growing season. A summary of the results is presented in Table III.

TABLE III—A Summary of the Results Obtained with Oil Sprays for Weed Control in Carrots

Material	Total Expts.	Weed Control		Injury to Carrots*		
		Good	Poor	None	Slight	Severe
Fuel oil No. 2	16	16	0	2	3	11
Kerosene	11	9	2	9	2	0
Stove oil	11	9	2	0	9	2

*When leaf margins were injured slightly, and when the plants could not be distinguished from the checks when they were half grown, the injury was considered "slight". Permanent stunting or death were considered severe injury.

Kerosene was least toxic to carrots and fuel oil No. 2 the most toxic. The wide variation in the results obtained with fuel oil and kerosene is to a large extent due to the fact that they were obtained from three different sources. In two experiments where the fuel oil

was not injurious to carrots, or only slightly so, kerosene from the same source gave poor control of weeds. Kerosene from another source gave good weed control. In two experiments where fuel oil was severely toxic, kerosene from the same source gave no injury and good weed control. Stove oil (all from the same source) was severely toxic in two of eleven experiments. In both instances the carrots were just beginning to show their first true leaf. In the remaining experiments the carrots had from three to five true leaves and were only very slightly injured. In the two trials with stove oil where poor weed control was obtained there was a high percentage of ragweed present.

Discussion

The Nature of Oil Toxicity:—There are two general types of injury to plants from oil sprays. Crafts and Reiber (1944) class them as (1) acute, in which the tissue in contact with the oil becomes necrotic within a day or two, and (2) chronic, in which tissues in addition to those sprayed are affected. In this case as long as 2 or more weeks may elapse after spraying before serious injury is apparent. Injury of the latter type was reported by Loomis (1936 and 1938) on dandelion. The oil was translocated to the taproot and injured the phloem and xylem.

Young (1935) has shown that oils are translocated in onions and potatoes, and that with the latter crop the oils are located principally between the parenchyma cells. He also reports that certain oils persist in potato tissues for several months. The specific causes of death according to Young are injury by physical suffocation, and toxic substances in the oil.

In the present experiments the injury reported was of the acute type. It did not appear to be caused by a suffocation of the tissues, but rather by some toxic compounds in the oils. According to Crafts and Reiber (1944) the toxic substances in the oils are probably certain aromatic compounds.

Tolerance was not due to the plants not absorbing the oils, for within a few seconds after spraying even the tolerant crops absorbed sufficient oil for the leaves to look water soaked and translucent. Carrot roots contained oil which had probably been translocated from the leaves. It was not a matter of the oils seeping down the leaves and getting on the surface of the carrot, for peeling did not eliminate the objectionable flavor of recently sprayed carrots.

Factors Affecting Oil Toxicity

The kind of oil materially influences the results. There are probably three factors involved: the type of crude, the method of refining, and the specifications. Crafts and Reiber (1944) believe the type of crude and method of refining are important because of their influence on the aromatic content of the oil. They believe the boiling point is important because heavy oils are likely to be injurious and the light ones are likely to evaporate too quickly. In these experiments the

kerosene and fuel oil, althougth obtained from three different sources met the same respective specifications. It is likely, therefore, that their differential affects were due to the type of crude, or method of refining or to a combination of these two factors.

Environmental factors influence the toxicity of oils. When the foliage was wet, particularly when the oils were applied during a rain, the toxicity was markedly increased. For example, in one experiment with carrots when kerosene was applied to dry foliage the rate could not be less than 1 gallon per 100 foot of row for satisfactory weed control. This rate could be cut in half, however, when the foliage was wet. Crafts and Reiber (1944) report greater toxicity in warmer weather than in cooler weather. Loomis (1938) on the other hand found better results at temperatures below 23 degrees C than at higher temperatures. The present experiments tend to support Loomis, for applications in the greenhouse at temperatures of 95 degrees F did not increase the toxicity of stove oil above that observed when applied at 75 degrees F. It should be noted, however, that the effects of rainfall in Loomis' work and in many of the present experiments was not definitely separated from temperature.

The age of the crop is an important consideration. Raynor states that carrots should have from one to four true leaves. In the present experiments, however, serious injury resulted when carrots having only one true leaf were sprayed. Those having three or more true leaves were rarely seriously injured. Although no odor in the raw or cooked roots could be detected 8 weeks after spraying, there was a slight odor while the roots were being cooked 2 weeks after spraying.

Summary

Stove oil, a Western petroleum product similar to Eastern kerosene, gives satisfactory weed control when sprayed on carrots at about 150 gallons per acre. Certain types of eastern kerosene and fuel oil No. 2 can be satisfactorily substituted for stove oil. As yet it is not known how to predict before trial which types of kerosene and fuel oil will be satisfactory. Carrots should have at least two true leaves before oil sprays can be safely used. The toxicity of oils is increased by applying them when the foliage is wet. Members of the Umbelliferae family: carrots, celeriac, turnip-rooted parsley, and, to a limited extent, celery, are tolerant of oil sprays. Ragweed, wild carrot, galensoga, and a few grasses are the common weeds tolerant of oil sprays, whereas purslane, red root, lamb's quarters, and most grasses are very susceptible.

There are many phases of the problem of weeding carrots with oil sprays needing further investigation. A few of the more important ones are: Is there any harmful build-up of oil residues in the soil after several years use? What are the specific oil fractions and aromatic compounds causing acute toxicity? Why are some plants tolerant of and others susceptible to oil sprays? How do pressures and rates of application effect efficiency and toxicity? What specific climatic conditions effect toxicity?

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The Use of Oil Sprays as Selective Herbicides for Carrots and Parsnips[1]

By WILLIAM H. LACHMAN, *Massachusetts State College, Amherst, Mass.*[2]

A CONSIDERABLE amount of hand weeding is generally necessary in the culture of carrots and parsnips. The prompt removal of weeds is important early in the development of the crop to prevent competition for nutrients, moisture, light, and air. If this competition is not removed, satisfactory yields cannot generally be realized.

It has recently been found in California (3, 4) that all or practically all of the hand weeding of carrots and parsnips can be eliminated and that the weeds can be successfully destroyed with stove oil when sprayed on and between the crop rows without damaging the crop plant. Stove oil is not available in the East, but further investigation (2, 5) has shown that certain other petroleum fractions are equally valuable for use as selective herbicides. The purpose of this report is to present the results of experiments using several petroleum fractions as oil sprays in carrot and parsnip plantings.

MATERIALS AND METHODS

Two oils distributed by the Standard Oil Company of New York have been used as sprays in these investigations. The first of these is known as Sovasol No. 5 and is most generally used as a paint thinner as well as for dry cleaning clothes. The other material used was a mixture of one part Sovasol No. 75, a paint thinner, and two parts of white kerosene. Carrots either succumbed or were severely burned when Sovasol No. 75 was used without kerosene as a diluent.

The oils were applied with a Brown Gold Medal knapsack sprayer fitted with Monarch nozzle No. 59 (0.059 inch orifice diameter). This nozzle delivers a flat, fan-shaped spray and gives a very uniform coverage.

Both of the oils were applied to carrots and parsnips in various stages of development. The forenoon of a bright sunny day was the time generally chosen to apply the spray.

RESULTS

The results of spraying weeds in various stages of development have shown that it is most advantageous to apply the spray in the early stages of weed growth. The sprays appeared to be most effective when the weeds were 2 to 3 inches high and growing rapidly. Small succulent weeds were quickly killed with little or no difficulty, while the large, tough, thick-leaved weeds were not quite so susceptible to the effects of the spray. The sprays did not give very satisfactory results after the weeds became larger than 5 or 6 inches tall. Large tough weeds were considerably more susceptible when the sprays were applied

[1]Contribution No. 543 from Massachusetts Agricultural Experiment Station.
[2]The author wishes to acknowledge the valuable suggestions made by Dr. O. H. Pearson of the Eastern States Farmers' Exchange, West Springfield, Mass.

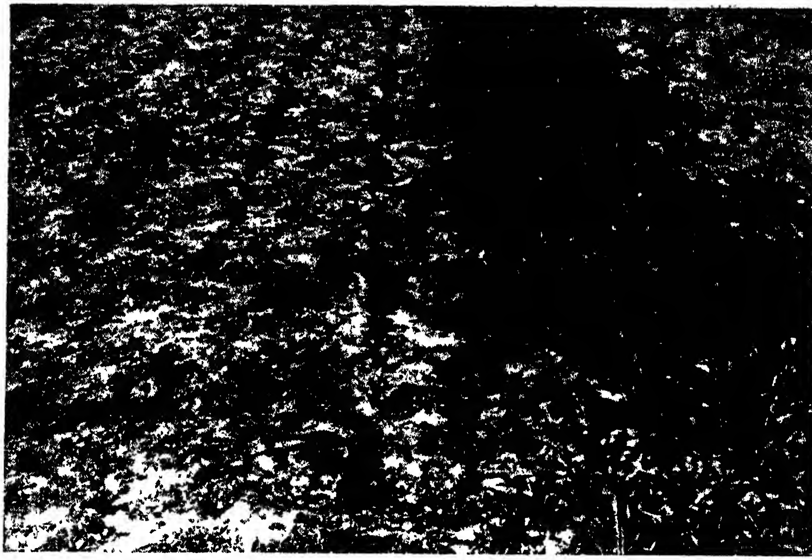

FIG. 1. These carrots were planted on July 21 and the rows on the left were sprayed August 22 with Sovasol No. 5 at the rate of 80 gallons per acre. At the time of spraying most of the carrot plants had four true leaves. Note vigorous growth of weeds in check rows at right. The photograph was made on August 31, 1944.

FIG. 2. This photograph, made on October 4, 1944, shows the later development of the crop illustrated in Figure 1. The crop was not cultivated at any time.

about 3 or 4 days after a half-inch of rain had penetrated into the soil. It is suspected that other weather conditions may affect the success of these oil sprays, although Raynor (3) did not find this to be the case in his experiments with stove oil. Sweet *et al.* (5) reported that when the foliage was wet and particularly when the oils were applied during a rain, the effectiveness of the oils was markedly increased. Crafts and Reiber (1) found that the oils were more toxic to weeds in warmer weather than in cooler weather but the results of Sweet *et al.* (5) do not support this conclusion.

The sprays acted very quickly and within an hour after they were applied, the weeds were definitely wilted. Inside of 3 or 4 days the complete weed population that had been hit by the spray was dead. None of the weeds encountered (White, Green, and Common Pigweeds, Lamb's Quarter, Galensoga, Fall Grass and Purslane) presented any particular difficulty of control provided the sprays were applied when the weeds were small.

No apparent injury has resulted to carrot or parsnip leaves from spraying with either Sovasol No. 5 or the Sovasol No. 75, kerosene mixture. A small percentage of carrot leaves developed a lighter color after spraying but this disappeared in about a week without any other noticeable effect.

The regular nozzle for spraying insecticides that delivers the cone type spray was used in a few tests but was found to be generally unsatisfactory since it gave only about 60 per cent as good weed control as the nozzle delivering a flat, fan-type spray.

Approximately 80 gallons of oil per acre were required to control weeds under ordinary conditions. Under some conditions, however, as much as 100 gallons of oil may be required, depending on the row width, prevalence and size of weeds, and the variation in spraying equipment. At the stated rates of application the material to spray an acre would cost from 12 to 15 dollars at present prices.

The petroleum sprays described here seem to be highly selective for members of the Umbelliferae family such as carrots and parsnips. The Sovasol No. 75, kerosene mixture, was sprayed on lettuce, however, with good results. It burned the outer leaves of lettuce somewhat but the plants quickly recovered and produced an excellent crop. The sprays completely destroyed young beet and turnip plants, indicating that these oils are very damaging to some crops. Tests should be made with all crops to ascertain the effect of the sprays before large areas are treated.

One precaution has come out of the spraying experiments in California (3) where stove oil was used for killing weeds. This is a warning that carrot plants should not be sprayed after they have developed four leaves or the roots will have an oily taste and odor after they have been cooked. Stove oil similar to that used in California is not available in the East. Carrots that had been planted on June 15 and sprayed with Sovasol No. 5 on July 18, July 21, and August 2 were harvested on October 2, and cooked on October 3. There was no perceptible oily flavor and the carrots tasted normal in every respect both in the raw state and after they had been cooked.

Summary

Sovasol No. 5 and Sovasol No. 75 mixed with two parts of white kerosene have been found to be valuable as selective herbicides in fields of carrots and parsnips. No apparent damage to carrots or parsnips resulted from either of these sprays. Carrots sprayed three times with Sovasol No. 5 gave no hint of an oily flavor when eaten fresh or cooked. Operational costs and the number of man hours required for weed control with the oil sprays used in these experiments were considerably less than those required for hand weeding. Crops other than members of the family Umbelliferae were injured by the oil sprays in varying degrees of severity and some crops were completely killed.

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The Effect of Copper Sprays, Fertilizers and Shade on the Growth of Pepper Seedlings[1]

By B. L. Richards, Jr. and R. D. Sweet, *Cornell University, Ithaca, N. Y.*

Abstract

The complete paper will appear at a later date in *Phytopathology*.

Seedling peppers are sometimes sprayed with copper fungicides as a control for damping-off. Growers report that injury to the growing point sometimes results when a proprietary product containing 50 per cent copper oxychloride sulfate, (25 per cent metallic copper) is used. The injury appears to be most severe where high fertilization is practiced, and in periods of low light intensity.

A series of experiments to determine the affects of copper sprays, shade, and fertilizer, particularly nitrogen, were conducted with California Wonder pepper seedlings in a 70–80 degrees F greenhouse. The seedlings were started in a fertile compost and pricked out in about 2½ weeks into flats holding 24 plants at a 2 x 2-inch spacing. Treatments started one week after pricking out, and were factorially arranged. Results were analyzed by analysis of variance.

In preliminary experiments conducted in November a sandy soil (pH 5.6) of very low fertility was used at the time of pricking out. At weekly intervals the plants were sprayed at the rate of 8 pounds of copper oxychloride sulfate (55 per cent metallic copper) per 100 gallons. Just prior to spraying, applications of nitrate of soda at the rate of 100 pounds per acre on an area basis were made and thoroughly washed into the soil. An equivalent amount of water was applied to those not receiving nitrate. One-half of the plants were lightly shaded by means of black cloth that eliminated direct sunlight, but which had little effect on cloudy days.

Seven weeks after pricking out, the seedlings were not injured except where nitrate had been added, in which case an average of 66 per cent of the plants either were dead or severely injured in the spray treatment. An average of 33 per cent of the plants showed similar injury where no spray was applied. No wilting or root injury occurred. There was no significant effect of the shade.

Experiments were designed to learn more about the role of nitrogen in causing the injury. A compost soil (pH 7.45) of high fertility was used in addition to the infertile sand. Nitrate of soda was mixed with the soil in some flats at the rate of 300 pounds per acre. It was also applied on top as before but in solution. A commercial 5–10–5 fertilizer was used as was nitrate of soda at a rate which would supply equivalent quantities of nitrogen. Light shade was used. Instead of undiluted copper oxychloride sulfate, COCS Spray, the proprietary product often used by growers was applied.

These experiments showed that the injury to the growing points was significantly less when the nitrogen was supplied as 5–10–5 than

[1]Paper No. 267. Department of Vegetable Crops, Cornell University, Ithaca, New York.

when applied as nitrate. The method of application had no significant effect on injury. In contrast to the earlier experiments there was no injury except where sprays were applied. Light shade had no effect. As will be discussed later, fertilizer had a significant effect on growth. The earlier experiments were conducted in November. The later ones were conducted in March and April when light was more intense.

To test the difference in light intensity more thoroughly the lightly shaded flats were heavily shaded. This reduced the light intensity on bright days from an average of 5500 to an average of 60 foot candles. Seedlings developed necrotic areas at the base of the young leaves within 10 days after the heavy shade was applied. The injury soon progressed so that entire leaves and growing points became necrotic. Within three or four days after the injury was first noticeable, many plants died. The injury was not correlated with spray or fertilizer treatment and was distinct from and much more severe than that caused by the spray. In its later stages the injury resembled that observed in the preliminary experiments.

Growth, as measured by height, was significantly influenced by the soil, fertilizer and spray treatments. The compost soil produced much taller plants than did the sand. Nitrate of soda mixed with the soil greatly reduced growth. When applied in solution, however, the reduction was significant only in the sand series. Plants in the compost made no response to the complete fertilizer but those in the sand responded favorably. Spraying reduced their height. Spray injury was not directly correlated with height or succulence, but was most severe when nitrate of soda stunted plant growth.

Since the results with spraying did not agree with those obtained earlier, an experiment was designed to test the difference between the proprietary product COCS Spray and the undiluted copper oxychloride sulfate. A 5-10-5 fertilizer was used as the source of nitrogen, and the plants were pricked out into the low fertility soil. Light shade was used. There was no significant effect of the shade. The fertilizer caused only a slight increase in the number of seedlings injured. The difference between spray materials was highly significant. The COCS Spray caused injury to 33 per cent of the seedlings whereas the undiluted material injured only 5 per cent. Experiments are now under way to determine why the diluted material was so much more toxic.

Summary

Certain copper sprays are sometimes toxic to pepper seedlings and this toxicity is increased by the use of nitrogenous fertilizers. Nitrate of soda applied at the rate of from 50 to 75 pounds of nitrogen per acre may cause injury and even death to pepper seedlings. The specific cause of the nitrogen injury is not known, but is thought not to be due to excessive osmotic concentrations of the soil solution. The light intensity or day length probably affects the toxicity of nitrogen but the evidence from these experiments was inconclusive. Nitrate of soda reduced growth of pepper seedlings when applied to a soil of low fertility at the rate of 300 pounds per acre.

Relation of Yield of Oil from Peppermint (Mentha Piperita) and the Free Menthol Content of the Oil[1]

By N. K. Ellis and F. C. Gaylord,[2] *Purdue University, Lafayette, Ind.*

The stage of maturity at which essential oil bearing plants should be harvested is most difficult to determine. In the past, several empirical or rule-of-thumb methods have been used for determining the proper time for cutting peppermint (*Mentha piperita* L.). The appearance of blossoms on the plant, the bronze coloration of the leaves and the ratio between leaves shed at the bottom of plant to new ones growing out at the top have all been used to indicate the best time for cutting mint. However, none of these are reliable since meadow mint (planting at least 2 years old, covers all the soil) often does not bloom, the bronze coloration of the leaves may be due to potash deficiency, and it is impossible to determine the exact stage at which the loss of old leaves at the bottom of the plant exceeds the gain in new leaves at the top.

The work on time of cutting peppermint was begun in 1938. The data for the years 1938, 1939 and 1940 were published in 1941 (1). It was observed from this early work that the calendar date had little to do with the cutting date. Complete chemical analyses were made and it was concluded that, "The data on date of cutting show a progressive increase in the per cent of total menthol and in the per cent of esters with delayed cutting. These appear to be the two best indicators of the stage of maturity of the oil". Later data indicated that the best time to cut was when the total menthol content of the oil approached 50 per cent. This information was practically useless without extensive chemical equipment and well trained chemists.

In 1943, a viscometric method for determining free menthol in peppermint oil was developed by Drs. L. J. Swift and M. H. Thornton of the Purdue Agricultural Experiment Station (2). It was then found that there was a direct relation between the free menthol content and the yield of oil.[3] The general pattern is repeated every year with both row (first-year mint planted in rows) and meadow mint.

The oil content of the peppermint (*Mentha piperita* L.) increases up to a certain point (the oil contains about 45 per cent free menthol) and if the plant is allowed to stand, the yield of oil decreases while the free menthol increases. In a comparatively short period of time, 10 to 15 days, the decrease may amount to as much as 30 per cent of the total yield of oil. Within the same period of time preceding the highest yield, the yield may increase 10 to 15 pounds per acre or as much as

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[1]Journal Paper No. 179—Purdue University Agricultural Experiment Station.

[2]The chemical analyses were made by Dr. L. J. Swift, Department of Agricultural Chemistry, Purdue University, and Dr. L. H. Baldinger, Dean of the Science School, Notre Dame University.

[3]Practical use of the Free Menthol Test is described in Horticultural Department Mimeograph No. 3, of the Purdue University Agricultural Experiment Station, 1944.

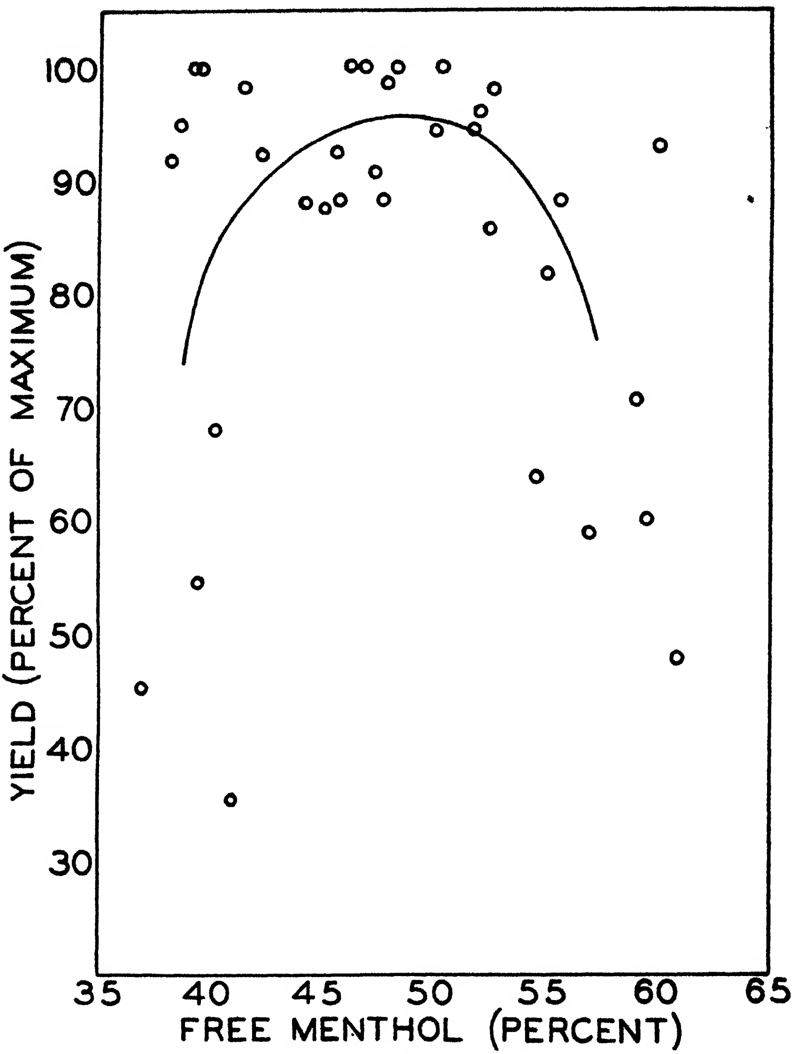

FIG. 1.* Relation between the free menthol content of peppermint oil and the yield per acre.

*The data in Fig. 1 represent both row and meadow mint for the years 1941, 1942 and 1943. For each season, the earliest harvest is toward the left while the latest is toward the right. In order to eliminate differences in yield due to weather conditions and methods of planting, the maximum yield of row and of meadow mint for each year was represented as 100. All lower yields were calculated as percentage of this maximum. The numerical data for this curve are given in the last column of Table I.

30 per cent of the total yield. It is therefore very important to the grower to be able to estimate the right time to cut mint for the highest yield.

Experience has shown that the free menthol seldom exceeds 60 per cent but that the total menthol, which includes the free menthol as well as that combined in the form of esters, may be considerably greater than 60 per cent. The curve (Fig. 1) shows the rise and fall of the yield of oil and shows the continued increase in menthol content of the oil throughout the season.

From the data shown on the curve (Fig. 1) and Table I, it may be concluded that if the free menthol content of the oil is below 41 per cent, the peppermint is not ready to cut. If the free menthol content is between 41 and 43 per cent, the peppermint is approaching the

TABLE I—DATE OF CUTTING, YIELD AND ANALYSES OF PEPPERMINT OIL FOR THE YEARS 1941, 1942 AND 1943

Date of Cutting	Esters (Per Cent)	Total Menthol (Per Cent)	Per Cent Free Menthol Calculated from Chemical Analysis	Viscometric Determination of Free Menthol	Yield (Pounds Per Acre)	Yield (Percentage of Maximum)
			1941 Meadow Mint			
Jul 28	5.17	48 32	44.28	46.2	56.1	88.0
Aug 4	5.0	46.2	42.3	—	49.5	92.2
Aug 12	5.77	51.3	46.8	48.5	63.8	100.0
Aug 22	6.69	60.27	55.0	53 9	52.1	81.7
Aug 27	7.6	64.94	59.0	57.2	45.0	70.6
Sep 3	8.14	65.87	59.52	60.2	38.3	60.0
Sep 8	10.53	69 08	60.83	59.2	30.5	47.8
			1941 Row Mint			
Aug 4	4.88	40.75	36.9	38.4	25.12	45.3
Aug 12	5.22	42.76	38.7	—	52 6	95.0
Aug 22	6.95	53.76	48.3	—	55.4	100.0
Aug 27	6.8	57.4	52 0	—	53.2	96.1
Sep 3	7.67	58.6	52 6	—	54.3	98.0
Sep 8	8.58	66 6	59.89	—	51.5	93.0
			1942 Meadow Mint			
Jul 13	5.29	50.38	46.3	46.2	41.5	100.0
Jul 20	5.7	52.35	47.9	47.9	41.0	98.7
Jul 27	7.16	61.16	55.6	55.5	36.6	88.2
Aug 3	8.25	63.32	56.87	—	24.4	58.8
			1942 Row Mint			
Jul 13	4.66	44.78	41.18	41.2	20.7	35.2
Jul 20	5.86	44.82	40.24	40.9	40.0	68.0
Jul 27	5.55	43.68	39.34	—	58.8	100.0
Aug 1	5 4	49.87	45.67	45.4	54.3	92.5
Aug 9	6.05	52.08	47.36	47.8	53.2	90.6
Aug 26	8.75	61.36	54.53	—	37.5	63.8
			1943 Meadow Mint			
Jul 20	5.72	49.6	45.1	46.2	20.6	87.4
Jul 26	6.71	51.05	45.8	47.1	20.8	88.2
Jul 31	7.08	53.25	47.7	48.4	20.8	88.2
Aug 8	7.09	55.8	50.3	50.7	23.6	100.0
			1943 Row Mint			
Jul 31	3.93	42.55	39.49	40.8	25.3	54.7
Aug 8	4.37	41.65	38.25	39.2	42.5	91.8
Aug 15	4.41	44.9	41.5	42.8	45.5	98.3
Aug 18	4.36	42.7	39.3	42.1	46.3	100.0
Aug 28	6.26	54.95	50.1	50.7	43.7	94.5
Sept 2	7.20	57.35	51.7	52.2	43.7	94.5
Sept 8	8.08	58.65	52.35	53.9	39.7	85.7

stage of maximum oil yield and another sample of herb should be cut and distilled within 2 to 5 days. When the free menthol content equals or exceeds 45 per cent, the yield is probably near its maximum and the peppermint should be cut immediately.

Discussion

The practical importance of being able to tell maturity in the peppermint plant is shown by observing the calendar date of the highest yield for the years 1941, 1942 and 1943. From Table I it is seen that the row mint varied from August 22 in 1941 to July 27 in 1942 and to August 18 in 1943. The meadow mint which matures earlier than the row mint, produced its highest yield on August 12, 1941; July 13, 1942; and August 8, 1943. It is therefore evident that seasonal variation eliminates being able to estimate a cutting date by the calendar. In dry harvesting periods, the grower has more time to decide when to cut since the rise and fall of the yield is more gradual. The row mint in 1941 is illustrative of this, remaining within 5 per cent of the top yield from August 12 to September 3. The data on row mint for 1942 illustrate the opposite condition; the rapid rise and fall of the yield of oil, and the saving which can be made by the grower by using these facts.

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Studies on Various Methods of Handling Chrysanthemum Cuttings

By Alex Laurie and Stephen Ray, *Ohio Agricultural Experiment Station, Wooster, O.*

Tests were made in 1943 and 1944 in an effort to find a way to reduce the labor required to produce a properly grown crop. In addition, a test was made in 1943 to determine the difference, if any, in production of chrysanthemums with various root lengths of cuttings at the time of removal from the propagation benches.

1943 Tests

Test A: A Preliminary Test of Planting Unrooted Cuttings Direct to the Bench:—Standard varieties used were Anaconda and Penrod; pompon varieties used were Navaho and Cassandra. The unrooted treated (concentrated dip method — indolebutyric acid, 5 mg per 100 ml) cuttings were planted direct to the bench May 18. The soil was light and well drained. The cuttings were shaded with wrapping paper and syringed often the first week to prevent excessive wilting. Results are indicated in Table I.

TABLE I—Test A—Preliminary Test for Planting Unrooted Chrysanthemum Cuttings Direct to the Bench—May 18, 1943

Treatment	Variety	Per Cent Loss	Standards			Pompons		
			Average Length (Inches)	Average Flower Diam (Inches)	Salable Flowers Per Plant	Ounces Per Plant	Average Length (Inches)	Plants Per Bunch
		Soil	Soil	Soil	Soil	Soil	Soil	Soil
300 unrooted	Anaconda	1	44	6 5	1.7	—	—	—
cuttings direct	Penrod	0	46	5.0	1.8	—	—	—
to bench	Navaho	0	—	—	—	3.6	44	2.5
May 18, 1943	Cassandra	0	—	—	—	2.0	42	4.5

The low percentage of loss as shown in Table I was due principally to the weather conditions at this early date. The week of May 18–25 was cool and cloudy and only one per cent of the plants benched was lost. This early planted test indicated the feasibility of the method.

Test B: Methods of Planting Chrysanthemums:—All tests were run in duplicate, in soil and in gravel. All plant material was benched June 7. Standard varieties used were Anaconda and Penrod; pompon varieties used were Navaho and Cassandra. Each plot contained 80 plants of each variety, making a total of 320 plants per plot. Plots and treatments were as follows:

1. Unrooted cuttings planted direct to bench in light, well drained soil, shaded with paper or cloth and syringed often the first two weeks to prevent excessive wilting.

2. Rooted cuttings that had been taken May 18 were planted direct to the bench June 7 in light, well drained soil, shaded with paper or cloth and syringed often the first 10 days to prevent excessive wilting.
3. Rooted cuttings received May 18 were potted in 2-inch pots May 18 in light, well drained soil, shaded and syringed often to prevent excessive wilting. The plants were benched June 7.
4. Unrooted cuttings were potted directly into 2-inch pots May 18 in light, well drained soil, shaded and syringed often to prevent excessive wilting. The plants were benched June 7.
5. Unrooted cuttings, stuck in sand May 18 to root, potted in 2-inch pots May 27, then benched June 7.

The soil for tests A and B was a mixture of one-third well rotted manure and two-thirds silt loam. All soil mixtures used in chrysanthemum tests were steam sterilized. In addition, the soil in the bench in which cuttings were planted direct (Test A and Test B, plots 1 and 2) had one inch of sterilized sand incorporated in the top two inches of soil after sterilization to produce better drainage and aeration.

The media used in the gravel culture benches was B-grade haydite. The gravel culture bench in which cuttings were planted had fine haydite, FF-grade, incorporated in the top two inches. This prevented too rapid drying in the B-grade haydite where drainage and aeration was more than adequate.

Except for the shading and syringing, the cuttings which were planted direct to the bench were grown as usual after benching. Particular attention was given to regular soil and solution tests, and after the plants were established the nutrient levels were maintained as follows:

TABLE II—NUTRIENT LEVELS* MAINTAINED FOR SOILS AND SOLUTIONS IN PARTS PER MILLION

	Soil	Solution
pH	6.5 to 7.0	6.0 to 6.8
Nitrates	10 to 25 ppm	300 to 400 ppm
Phosphorus	5 to 10 ppm	20 to 50 ppm
Potassium	5 to 20 ppm	60 to 100 ppm
Calcium	100 to 150 ppm	100 to 150 ppm

*Soil and solution tests were made by the Spurway soil test method.

During the week of June 7–14 the days and nights were warm and losses were high for some plots and varieties as shown in Table III. Because of the warm weather, the cuttings wilted severely and syringing was of necessity frequent. The slightly higher percentage of loss in the gravel beds may be due to the frequent syringings. The unrooted and rooted cuttings planted direct to the bench wilted severely, and the ball of soil around the roots of the plants in gravel did not dry sufficiently to allow adequate aeration of the roots. Cooler weather at the time of benching (Test A) is more conducive to a low percentage of loss.

TABLE III—Test B—A Comparison of Methods of Planting Chrysanthemums Benched June 7, 1943

Treatment	Variety	Per Cent Loss		Standards						Pompons					
				Average Length (Inches)		Average Flower Diameter (Inches)		Salable Flowers Per Plant		Ounces Per Plant		Average Length (Inches)		Plants Per Bunch	
		Soil	Gravel	Soil	Gravel	Soil	Gravel	Soil	Gravel	Soil	Gravel	Soil	Gravel	Soil	Gravel
Unrooted cuttings direct to bench	Anaconda	13	24	43	44	5.75	5.75	1.7	1 5	—	—	—	—	—	—
	Penrod	0	3	49	50	4.50	4.75	1.9	1.9	—	—	—	—	—	—
	Navaho	25	9	—	—	—	—	—	—	3.8	3 3	40	41	2.4	2.7
	Cassandra	19	20	—	—	—	—	—	—	4.5	3.6	35	37	2.0	2.5
Rooted cuttings direct to bench	Anaconda	0	3	41	46	6.25	5.75	1.8	1.9	—	—	—	—	—	—
	Penrod	1	4	42	45	5.00	4.75	1 4	1.6	—	—	—	—	—	—
	Navaho	17	3	—	—	—	—	—	—	5.4	2.1	37	37	1.7	4.3
	Cassandra	1	10	—	—	—	—	—	—	4.3	4.8	35	36	2.1	1.9
Rooted cuttings potted then benched	Anaconda	0	0	48	48	6.00	6.00	1.6	1.7	—	—	—	—	—	—
	Penrod	0	2	52	42	4.50	4.75	1 4	1.7	—	—	—	—	—	—
	Navaho	0	0	—	—	—	—	—	—	3 7	2 9	50	45	2.4	3 1
	Cassandra	0	33	—	—	—	—	—	—	4.5	5.4	42	40	2.0	1.7
Unrooted cuttings potted then benched	Anaconda	0	0	48	49	6 00	6 50	1.5	1.8	—	—	—	—	—	—
	Penrod	0	0	55	50	4.75	5.00	1.7	1.8	—	—	—	—	—	—
	Navaho	0	1	—	—	—	—	—	—	3 6	3 5	48	47	2.5	2.6
	Cassandra	0	8	—	—	—	—	—	—	4 5	5.7	44	42	2.0	1.6
Unrooted cuttings rooted in sand potted, then benched	Anaconda	0	0	48	49	6 25	6.50	1.7	1.8	—	—	—	—	—	—
	Penrod	0	3	55	50	4.50	5.00	1.7	1 8	—	—	—	—	—	—
	Navaho	0	0	—	—	—	—	—	—	4.3	3.5	53	46	2.1	2.6
	Cassandra	0	28	—	—	—	—	—	—	4 8	4.5	42	39	1 9	1 7

Test C: Length of Roots at Time of Potting:—Unrooted treated cuttings of Silver Sheen, a standard variety, were received and stuck in sand to be rooted May 18 (Series I) and June 2 (Series II). Cuttings were potted in 2½-inch pots when the roots reached the proper lengths, and were later shifted to 6-inch pots where they were grown two stems per plant.

Plots were set up in the following way: *Series I:* Cuttings were stuck in sand May 13 to be rooted. Rooted cuttings were removed in equal numbers as the roots reached the following lengths: Plot 1, ½-inch roots; Plot 2, 1-inch roots; Plot 3, 1½-inch roots; and Plot 4, 3-inch roots.

Plants were potted in 2½-inch pots when removed from the propagation bench and when established were shifted to 6-inch pots. *Series II:* Series II was a duplication of Series I except that the cuttings for Series II were stuck in sand June 2.

Results are indicated in Table IV.

Series I produced longer stems than Series II. The later starting date of Series II is the obvious reason.

The cuttings potted when the roots were three inches long produced shorter stems than the other cuttings in their respective series. The stems of the plants grown from cuttings with 3-inch roots became

TABLE IV—Test C—A Comparison of Production and Length of Roots at Time of Potting 1943

Series	Days in Sand	Length of Roots When Cuttings Were First Potted (Inches)	Flower Record		
			Average Stem Length (Inches)	Average Flower Diameter (Inches)	No. Flowers Per Plant
I Started May 13	7	1½	32	5	2.0
	10	1	35	5	2.0
	14	1½	35	5	1.9
	22	3	34	5	1.9
II Started June 2	12	½	30	5	2.0
	15	1	30	5	2.0
	19	1½	30	5	2.0
	27	3	29	5	2.0

hard while the cuttings were in the propagation bench. The somewhat harder stems of this group accounts for their failure to grow as rapidly as the other groups.

1944 Tests

Test D: Methods of Planting Chrysanthemums:—All varieties growing in the 1944 test plots are pompon varieties. Three varieties, blooming in late November and early December, are Seafoam, Nevada, and Goldsmith. The other three varieties are Snow, Vibrant, and Revelation, and they bloom in late December. The soil plots each contain 168 plants of the November-December blooming varieties and 198 plants of the late December blooming varieties. One-half of the late blooming varieties are being subirrigated, and one-half are being watered overhead. The gravel plots each contain 276 plants of the November-December blooming varieties.

Plots and treatments are as follows:

1. Unrooted cuttings potted, then benched. Seafoam, Nevada, and Goldsmith were potted direct in 2½-inch pots containing light sandy soil May 15. They were shaded and syringed until established, then benched June 5 in soil only. Snow, Vibrant, and Revelation were potted June 1, and benched June 20 in soil only.

2. Unrooted cuttings were propagated in sand, then benched. Seafoam, Nevada, and Goldsmith were stuck in sand May 15 to be rooted. The rooted cuttings were benched June 5 in both soil and gravel. Snow, Vibrant, and Revelation were stuck in sand to be rooted June 1, and then benched June 20 in soil only.

3. Unrooted cuttings were propagated in sand, fertilized, then benched. Seafoam, Nevada, and Goldsmith were stuck in sand May 5 to be rooted. The rooted cuttings were fertilized while still in the propagation bench May 26 with ammonium sulfate at one ounce to four gallons of water. The rooted cuttings were then benched June 5 in soil and gravel.

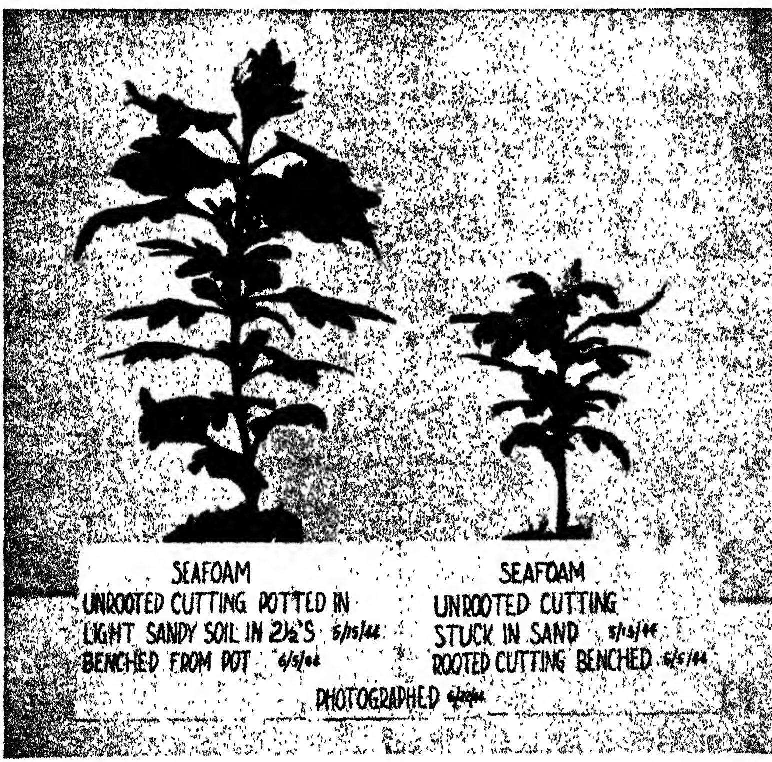
4. Rooted cuttings benched on arrival. Seafoam, Nevada, and

Goldsmith were benched June 6 in soil and gravel. Snow, Vibrant, and Revelation were benched June 20 in soil only.

5. Rooted cuttings potted, then benched. Seafoam, Nevada, and Goldsmith were potted May 15, then benched June 6 in soil only. Snow, Vibrant, and Revelation were potted June 1, then benched June 20 in soil only.

The soil mixture in the benches is two parts sandy loam and one part well rotted manure. The gravel culture bench contains B-grade haydite. Except for the changes in the treatments, the growing operations will be as near as possible to those for Test B, 1943.

There were no plants lost by the methods of benching as outlined in the treatments above. There were striking differences in the growth of the plants immediately after benching, especially between treatments 1 and 2. Fig. 1 shows this difference.



The plants photographed were representative plants from treatments 1 and 2 and show that unrooted cuttings potted, then benched, receive less check in growth when benched than do unrooted cuttings, rooted in sand, then benched.

At this date, production figures for the five treatments are not available.

Summary of the 1943 and 1944 Tests

Better growth can be obtained by the elimination of one or more of the steps in benching chrysanthemums. From the results to date of the tests with chrysanthemums for 1943 and 1944 it is evident that the following statements are true:

Methods of Planting:—1. Potting unrooted treated cuttings in a light, well drained soil, then benching, eliminates one operation and gives excellent results if attention is paid to usual cultural practices.

2. Planting rooted cuttings direct to the bench eliminates one operation but is not so safe as potting unrooted treated and then benching. It also gives the plant a greater check in growth than planting cuttings rooted in pots. If loss at planting time is kept to a minimum by shading and syringing and careful preparation of the bench, production can compete very well with production from the usual benching method. (Both of the above methods, especially rooting cuttings in pots previous to benching, have the distinct advantage of eliminating checks in growth after rooting. Better quality results as a rule.)

3. Rooted cuttings planted direct to the bench at the time of arrival are satisfactory and eliminate unnecessary labor. If handled carefully, they work out as well as the use of unrooted cuttings.

4. If unrooted cuttings are secured, no trouble should be experienced either by rooting these and planting from the propagating bench, or else potting the unrooted cuttings and benching after proper rooting. However, the unrooted cuttings potted, then benched, will receive less check in growth after benching.

Length of Roots:—The length of roots at the time of potting seems to be of little importance as long as the stem of the cutting is not allowed to harden before shifting.

The Possibility of Producing Forcing Stocks of Lily-of-the-Valley in New Hampshire

By W. D. Holley, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

Until the present war shut off the supply, forcing stocks of lily-of-the-valley were shipped to this country from Germany, France and the Netherlands. According to Whiteman (1), these stocks were grown as a side line by farmers who sold them to central packing and exporting concerns. Very little has been written about the culture of lily-of-the-valley "pips", but some information has been gleaned from Scott (2) and anonymous articles in old trade papers.

Since lily-of-the-valley thrives in the cool climate of New Hampshire, the production of pips of a quality suitable for forcing seemed quite possible. To explore this possibility the following experiment was designed.

Materials and Methods

In April 1942, plantings of three strains of lily-of-the-valley were made on one-eighth acre plots at Durham, New Hampshire. The rhizomes were planted in alternate rows made by a hand-type plow which was also used for covering. Rows were spaced 30 inches apart but subsequent observation points to the fact that closer spacing would be more economical. The spacing would depend upon the type of cultivator available but could easily be 18 to 20 inches between rows, or even closer.

The soil used had been cleared from woods two years previously. It was an acid sandy loam of low organic matter content and fairly low in fertility. Some manure had been applied to this land during the first two years it was in cultivation.

These plantings consisted of alternate rows of a German strain obtained from Michigan, a Holland strain obtained from New Jersey, and a local or "wild" strain hereafter designated the Sawyer strain. The pips planted were mixed sizes.

In September 1942, a few of the largest pips were dug for preliminary forcing trials and fertilizer applications were made to four plots running across the strain rows as follows: 0–20–20 and manure, manure alone, 5–8–7 and manure, and 5–8–7 alone. Manure applications were at the rate of nine tons per acre, a common rate of application to many vegetable crops.

The pips that were dug in September 1942, were heeled-in in a well-drained cold frame in sand and left until the ground began thawing in early spring. They were then dug and packed in boxes of sphagnum moss or pine wood shavings, moistened and placed in cold storage at 28 degrees F until forcing trials were started September 17, 1943, one year after digging.

Before forcing, it was necessary to regrade the pips because many included in the lot were not large enough to contain flower buds. Forcing trials were made in the chamber shown in Fig. 1, located in a lean-to type house with a northeastern exposure. Clean quarter-inch

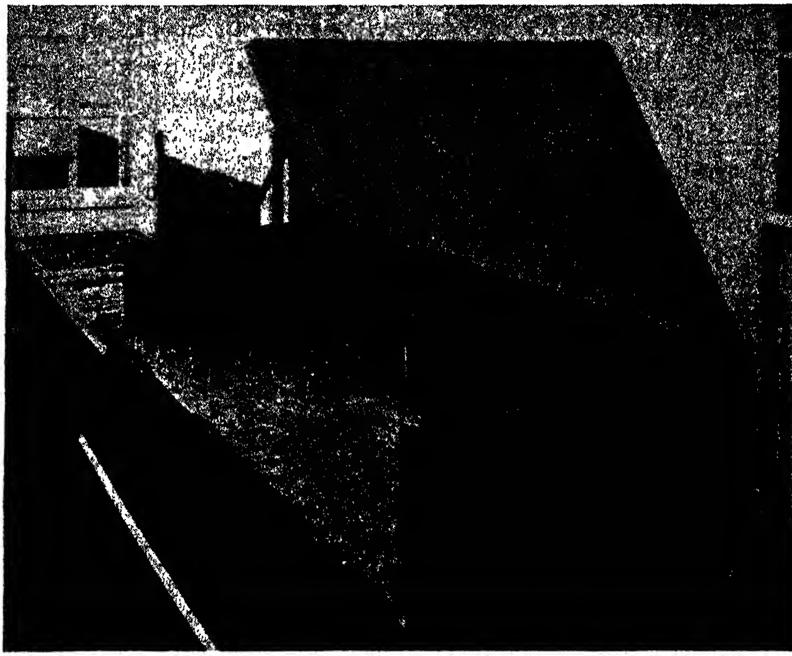


FIG. 1. A convenient forcing chamber for small lots of lily-of-the-valley.

mesh gravel 6 inches deep was used as the medium. This preliminary forcing trial was satisfactory in that it showed us that high quality blooms could be obtained from locally grown pips one year after digging. Those pips stored in sphagnum moss lodged and blasted their flower buds about the time heavy shade was taken off the frame. The roots of these pips were brown when thawed out, whereas, those stored in wood shavings were bright and healthy in appearance. Fig. 2 shows representative plants at the end of the forcing period. The cause of this browning may have been due to too much moisture held by the sphagnum moss. Later lots of pips were stored in wood shavings with excellent results. Of this first forcing only the New Jersey strain gave us high quality blooms. Although no bottom heat was supplied in this trial, the temperature of the medium was steady at 70 degrees F and the air temperature fluctuated from 55 to 85 degrees. Blooms were cut October 7, or 20 days after planting.

The entire planting was dug October 9, 1943, and placed in cold storage at 40 degrees F for grading from October 16 to 23. The field run pips consisted of four types as shown in Fig. 3. The 3-year-old pips were graded out, tied in bundles of convenient size and packed in boxes of moist wood shavings, with the roots to the inside. Apple boxes proved convenient for packing and handling in storage. These pips were placed in cold storage at 28 degrees F on October 23, and left until they were removed for forcing.

FIG. 2. Stocks on left were stored in sphagnum moss while those on the right were stored in moist wood shavings.

The chamber shown in Fig. 1 was used for all forcing trials made. The hinged front permits ease of planting and watering and the hinged top can be closed to shut out light. The top is covered with cheese cloth and on top of that a temporary heavy paper which may be removed when light is needed. Steam pipes were available underneath for bottom heat.

The first lot of pips from storage was thawed in water, washed, and placed in fine gravel on January 4, after approximately 2½ months in storage. Pips were set about 1 inch apart in rows 3 inches wide and to a depth that the top half of the pip was exposed after watering. Temperatures maintained were 70 to 72 degrees F for the medium and 60 to 75 degrees air temperature. The shade paper was removed 18 days after starting and the crop was cut in 28 to 35 days. This lot was rather irregular in flowering, probably due to low forcing temperatures for this early date.

The second lot was removed from storage and started March 18. Shade was removed in 15 days and flowers were cut in 27 days. This cut was more uniform than the earlier one although the same forcing temperatures were employed. The New Jersey strain was slightly later than either of the other two, so would have benefitted in stem length if shade could have been maintained several days more in each case.

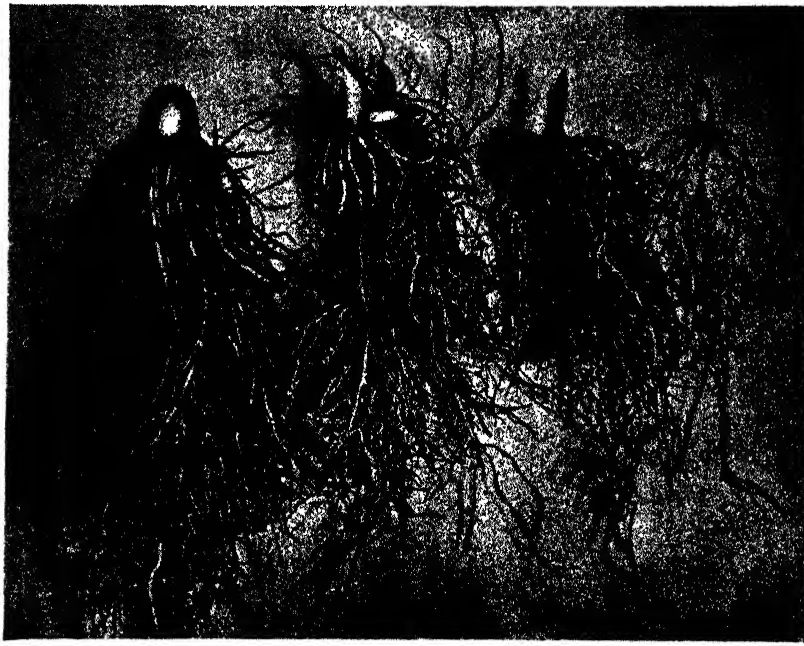


FIG. 3. From the left are flowering size or 3-year, 2-year with small current season, 1-year and current season pips.

RESULTS AND DISCUSSION

The influence of the fertilizer treatments on forcing quality of the pips is included in Table I. The table also gives a good comparison of the strains so far as their value for forcing is concerned.

From Table I it can be seen that the New Jersey, or Holland strain, stood out because of uniform length of stem, number of florets, and freedom from blasting. Flower stems were also stronger than those of either of the other strains. Whiteman (1) gives grading standards for lily-of-the-valley blooms as follows: Extra selected, 12 to 15 inch stems, with 10 to 15 bells on each stem; selected, 9 to 12 inch stems, with 10 to 15 bells; seconds, 7 to 9 inch stems, with 7 or more bells. Although this method of grading was not used, Table I shows that most of the treatments gave select or extra select blooms when compared to a former product imported from Europe.

As shown in Table I, manure and either 0–20–20 or 5–8–7 fertilizer increased both stem length and number of florets in the forced product. Manure alone applied at 9 tons per acre produced pips of good forcing quality. It is impossible to determine from these experiments whether or not the additional quality obtained by chemicals would be economically sound.

Table II shows that the strain is more important than the fertilizer treatment in influencing percentage of blasting. The only real differ-

TABLE I—THE INFLUENCE OF FERTILIZER TREATMENTS ON THE FORCING QUALITY OF LILY-OF-THE-VALLEY

Strain	Row	Number Forced	Per Cent Blasted	Number Salable Blooms	Ave Length	Ave Number Bells
Manure 9 Tons per Acre 0-20-20 800 Pounds per Acre						
Sawyer	2	0	—	—	—	—*
	5	10	30.0	7	9.7	13.1
	8	6	50.0	3	11.2	12.3
	Total	16	—	10	—	—
	Ave	—	37.5	—	10.1	12.9
Michigan	3	8	0	8	12.2	13.7
	6	11	36.0	7	12.1	12.8
	9	17	29.0	12	11.2	12.1
	Total	36	—	27	—	—
	Ave	—	25.0	—	11.7	12.8
New Jersey	1	10	0	10	11.5	13.8
	4	11	0	11	11.5	12.6
	7	5	0	5	11.8	13.2
	10	18	0	18	11.4	13.0
	Total	44	0	44	—	—
	Ave	—	0	—	11.5	13.1
Manure 9 Tons per Acre						
Sawyer	2	2	0	2	6.0	11 5*
	5	9	22.0	7	9.7	13.0
	8	0	—	—	—	—*
	Total	11	—	9	—	—
	Ave	—	18 0	—	8.9	12.7
Michigan	3	2	0	2	11.5	12.0
	6	8	25.0	6	11 9	12.3*
	9	11	45.0	6	10.9	12.3
	Total	21		14	—	—
	Ave	—	33.0	—	11.4	12.3
New Jersey	1	0	—	—	—	—
	4	6	0	6	11.2	13.0
	7	16	0	16	12.6	12.0
	10	14	7	13	12.3	12.2*
	Total	36	—	35	—	—
	Ave	—	3.0	—	12.2	12.2
Manure 9 tons per Acre 5-8-7 800 Pounds per Acre						
Sawyer	2	9	11 0	8	7.7	13.0*
	5	10	40.0	6	10.7	14.8*
	8	15	0	15	8.8	12.5
	Total	34	—	29	—	—
	Ave	—	18.0	—	8.9	13.1
Michigan	3	11	27.0	8	12.1	13.9*
	6	7	43.0	4	11.5	13.5
	9	17	18.0	14	11.1	14.1
	Total	35	—	26	—	—
	Ave	—	26.0	—	11.5	13.9
New Jersey	1	9	11.0	8	12.1	14 9
	4	0	—	—	—	—*
	7	15	0	15	9.2	12.1
	10	21	0	21	9.0	13.5
	Total	45	—	44	—	—
	Ave	—	2.0	—	9.6	13.3

*Included in January forcing which was slightly shorter than March forcing hence these will influence average stem length downward.

TABLE I (*concluded*)

Strain	Row	Number Forced	Per Cent Blasted	Number Salable Blooms	Ave Length	Ave Number Bells
5-8-7 800 Pounds per Acre						
Sawyer	2	24	54.0	11	8.3	13.0
	5	10	40.0	6	7.9	13.0
	8	0	—	—	—	—
	Total	34		17		
	Ave	—	50.0		8.2	13.0
Michigan	3	9	22.0	7	9.4	12.7
	6	0	—	—	—	—
	9	19	63.0	7	10.6	13.3
	Total	28	—	14	—	
	Ave	—	50.0	—	10.0	13.0
New Jersey	1	21	10.0	19	11.8	13.6
	4	8	12.0	7	8.1	12.5
	7	12	8.0	11	10.9	11.6
	10	32	0	32	10.4	13.0
	Total	73	—	69	—	—
	Ave.	—	5.5	—	10.5	12.9

ence shown in Table II is with the 5-8-7 fertilizer treatment and it is doubtful that this difference would be significant. There was, however, a slightly higher percentage of blasting in the earlier forcing. Whiteman (1) states that the average yield of salable blooms from European grown pips is about 80 per cent, so New Hampshire grown pips compare favorably with this figure.

TABLE II—Average Percentage of Blasting During Forcing

Strain	Fertilizer Treatment			
	Manure and 0-20-20	Manure	Manure and 5-8-7	5-8-7
Sawyer	37.5	18	18	50.0
Michigan	25.0	33	26	50.0
New Jersey	0.0	3	2	5.5

Conclusions

1. Lily-of-the-valley of high forcing quality can be grown successfully in a soil and climate such as southeastern New Hampshire.
2. Fertile, well-drained soil such as that used for intensive vegetable growing is suitable for lily-of-the-valley.
3. Pips grown in this experiment produced mostly select or extra select blooms.
4. The selection of proper strains is of supreme importance. The yield of salable flowers from the best strain grown was about 97 per cent of the pips planted, as compared to about 80 per cent for the expected average of European grown pips.

Literature Cited

1. Whiteman, T. M. Commercial forcing of lilies-of-the-valley. *U. S. D. A. Circ.* 215. 1932.
2. Scott, William. Floriculture. *Florists' Publishing Company.* 1906.

Register of New Fruit and Nut Varieties
List No. 1

By Reid M. Brooks and H. P. Olmo, *University of California, Davis, Calif.*

Foreword

THE origination and introduction of new fruit and nut varieties have become an increasingly important branch of horticultural endeavor. Details about such introductions, if made available to horticulturists and interested growers as soon as possible, will facilitate wider and more rapid testing of promising varieties. They will assist the fruit breeder in planning further work, will keep him abreast of the latest developments, and will more or less officially establish correct naming and facts that otherwise would eventually be lost or garbled. The aim is to make as complete a file as possible of each new fruit and nut originating in North America since and including the year 1920; to continue such records and make them freely available from time to time.

This project differs from any previous attempt in that original sources of information have been sought — usually the originator himself. Additional information has often been supplied by cooperating horticulturists in Experiment Stations and in the United States Department of Agriculture and by still others who are particularly well informed in this field of work. Only a minimum of basic information has been requested, as is shown by a facsimile of the Register card. Under present conditions, only such a cooperative method of reporting seems likely to keep the file reasonably complete and up-to-date. As a rule the data will be contributed by the person directly involved in introducing the new variety; thus there will be less chance for error than in copying printed material distributed later by other agencies. Those varieties not released for general planting are omitted.

At present the Register is not interested in the international aspects of nomenclature, nor in testing any varieties. In no sense is it considering the problem of variety names. It is not concerned with morphological descriptions, priority and legality of names, or type collections and herbarium specimens. Although full descriptions, specimens, and photographs would be a splendid supplement to the brief record we have asked for, at present this elaboration is not feasible. The Register does not attempt to evaluate any variety, nor suggest either codes or procedures. It merely records the data presented by the contributor — that is, by the originators themselves or by those instrumental in introducing the new variety. Such a cooperative project may at least show the way to a more extensive and comprehensive registration system for the future.

The difficulties of obtaining an accurate list are formidable, and any misnaming or misrepresentation of varieties will present no small obstacle. By soliciting the aid of those best able to report the data called for, however, errors will be kept to a minimum. To secure an accurate check, a prepublication list of the new varieties has been sent

to all participating horticulturists so that they may make any corrections or supply omissions before the material is printed. This plan is better than to rely upon published statements in nursery catalogs, newspapers, or trade journals, which are frequently more enthusiastic than accurate. Eventually the system should operate so that originators of new varieties will themselves report the information, while the University of California will maintain the files and publish periodic lists.

The present list — the first one published since the inception of the Register in April, 1942 — contains the data already received on introductions made during and since 1920. Where the parentage is known, the female parent is named first.

We shall be glad to learn of any variety released commercially to the trade during or since 1920. Register cards may be secured upon request from the Register of New Fruit and Nut Varieties, Division of Pomology, University of California, Davis, California.

Grateful acknowledgment is due to the many horticulturists who have made this compilation possible.

Name of variety ....

Synonyms..........

Originator..........

Firm or Institution..........

Address..........

Patent No..........Assigned to..........Date..........

Trademarked..........Date Introduced Commercially..........

Origin

Place of Origin..........

Date Discovered or Selected..........

Parentage.......... ♀ × .... ♂

Bud Mutation (Strain) of..........

Open Pollinated Seedling of..........Unknown..........

Most Nearly Resembles..........

Most Valuable Characteristics of New Variety..........

....

....

....

Information Contributed by:

Date:

FIG. 1. Facsimile of the Register card sent to secure information from the originators of new varieties.

Almond

Harpareil.— Originated in Davis, California, by the United States Department of Agriculture (M. N. Wood) and the California Agricultural Experiment Station (W. P. Tufts). Introduced commercially in 1938. Nonpareil × Harriott; cross of 1926, first crop 1930. Nut: large; color good; softshell; superior to Ne Plus Ultra, which it most nearly resembles. Tree: blossoms early; foliage and bearing habits good.

Jordanolo.— Originated in Davis, California, by the United States Department of Agriculture (M. N. Wood) and the California Agricultural Experiment Station (W. P. Tufts). Introduced commercially in 1938. Nonpareil × Harriott; cross of 1926, first crop 1930. Nut: large, smooth; attractive; quality high; softshell; kernel most nearly resembles Jordan. Tree: bears early and heavily; foliage dense; considerable resistance to spider.

Apple

Almeda.— Originated in Sumner County, Tennessee, by J. W. Savely. Introduced commercially in 1939. Patent no. 327. Mutation of Rhode Island Greening (?); discovered in 1927. Fruit: large; green; subacid; ripens July 25 to August 5; keeps exceptionally well; excellent for cooking.

Cauley.— Originated in Grenada, Mississippi, by the Mississippi Agricultural Experiment Station (J. W. Willis). Introduced commercially in 1942. Parentage unknown. Fruit: extremely large, weighing as much as 1 pound each; flesh yellow when ripe, with red skin stripes barely visible; flesh crisp and juicy; culinary and jelly apple; most nearly resembles Yellow Newtown. Tree: yields heavily, averaging 26 bushels per tree.

Conard.— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station. Introduced commercially in 1935. Ben Davis × Jonathan; selected in 1920. Fruit: large, well colored; quality good; flavor tart; texture fine-grained; ripens about 1 week after Jonathan; not subject to premature dropping. Tree: vigorous; bears regular crops; resistant to disease.

Double-Red Baldwin.— Originated in Salisbury, New Hampshire, by E. N. Sawyer. Introduced commercially in 1927. Bud mutation of Baldwin; discovered in 1924. Fruit: deep, brilliant red, coloring early; darker red than parental variety.

Double Red Delicious.— See **Starking.**

Double-Red Duchess — See **Red Duchess.**

Empire Red.— Originated in Grand Forks, British Columbia, Canada, by Robert Campbell. Introduced commercially in 1942. Patent no. 608. Parentage unknown; selected in 1928. Fruit: ripens early; skin all red; flesh streaked with red; ships well; used for cooking and dessert. Most nearly resembles McIntosh.

Faurot.—Originated in Mountain Grove, Missouri, by Missouri State Fruit Experiment Station. Introduced commercially in 1935. Ben Davis × Jonathan: selected in 1920. Fruit: ripens with Winesap; color fair; quality fair; size medium; keeps late; less likely to drop than Jonathan, which it most nearly resembles. Tree: resistant to disease.

Franklin.— Originated in Wooster, Ohio, by the Ohio Agricultural Experiment Station. Introduced commercially in 1937. McIntosh × Delicious; selected in 1936. Fruit: well colored; flavor mild; dessert quality high; combines flesh characteristics of each parent; extends McIntosh season 1 week; most nearly resembles Delicious in shape.

Fyan.— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station. Introduced commercially in 1935. Ben Davis × Jonathan; selected in 1920. Fruit: ripens 2 weeks after Jonathan; large; fairly well colored; attractive; fine keeper; resembles Jonathan. Tree: spreading; very vigorous; regular bearer of large crops: resistant to disease.

Grove.— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station. Introduced commercially in 1935. Ingram × Delicious; selected in 1930. Fruit: attractive; size good; quality good; colors

well before ripening; excellent keeper; ripens a little later than Winesap; most nearly resembles Delicious. Tree: blooms late; resistant to scab, blotch, blight.

Idared.— Originated in Moscow, Idaho, by the Idaho Agricultural Experiment Station (Leif Verner). Introduced commercially in 1942. Jonathan × Wagener; selected in 1935. Fruit: nearly solid red; core small; texture good; good keeper; excellent dessert quality. Most nearly resembles Wagener.

Jonared.— Originated in Peshastin, Washington, by William Uecher. Introduced commercially in 1934. Patent no. 85. Bud mutation of Jonathan; discovered in 1930. Fruit: earlier coloring than parent; all-over red color.

Minnetonka Beauty.— Originated in Excelsior, Minnesota, by I. E. Soderlund. Introduced commercially in 1941. Patent no. 474. Parentage unknown; selected in 1928. Fruit: no bunching on branches; used fresh and for cooking; keeps unusually long.

Newtown Delicious.— Originated in White Salmon, Washington, by E. P. Wray. Introduced commercially about 1937. Patent no. 61. Yellow Newtown × Delicious; selected about 1930. Fruit: attractive red and yellow color; flavor good; keeps well; superior for culinary use. Tree: growth vigorous; heavy bearer.

Red Duchess *(Van Buren, Double-Red Duchess).*—Originated in New York by J. P. Van Buren. Introduced commercially in 1937. Bud mutation of Duchess; discovered in 1914. Fruit: attractive solid red color.

Red Winesap.— Originated in Washington by the May Nursery Company. Introduced commercially in 1930. Parentage unknown; selected in 1928. Fruit: wine red; long type Winesap. Most nearly resembles Winesap.

Red York Imperial.— See **Yorking.**

Red Yorking.— See **Yorking.**

Scarlet Staymared.— Originated in Wenatchee, Washington, by J. H. Dickey. Introduced commercially in 1936. Patent no. 57. Bud mutation of Stayman Winesap; discovered in 1930. Fruit: solid red, which appears about 30 days before the coloring of Stayman Winesap.

Starking *(Double Red Delicious).*— Originated in Monroeville, New Jersey, by Lewis Mood. Introduced commercially in 1924. Trade-marked 1930. Bud mutation of Delicious; discovered in 1921. Fruit: similar to Delicious except for added color; perhaps better keeping quality than parent.

Staymared.— Originated in Covington, Virginia, by B. C. Moomaw. Introduced commercially in 1929. Bud mutation of Stayman Winesap; discovered in 1926. Fruit: solid red.

Valmore.— Originated in Visalia, California, by Val Moore. Introduced commercially about 1934. Patent no. 238. Parentage unknown; discovered about 1924 as a seedling. Fruit: ripens with White Astrachan; large; striped with red; excellent for cooking. Tree: productive; somewhat resistant to delayed foliation. Most nearly resembles Stayman Winesap.

Van Buren.— See **Red Duchess.**

Vance Delicious.—Originated in Albemarle County, Virginia, by R. G. Vance. Introduced commercially in 1935. Bud mutation of Delicious; discovered in 1930. Fruit: solid red, coloring at least 2 weeks earlier than Delicious.

Warder.— Originated in Wooster, Ohio, by the Ohio Agricultural Experiment Station (F. S. Howlett). Introduced commercially in 1937. Open-pollinated seedling of Rome Beauty. Fruit: attractive, red overcolor; dessert quality somewhat better than that of Rome Beauty; at Wooster, ripens in season of Grimes Golden to Jonathan (October 1); most nearly resembles Ensee.

Whetstone.— Originated in Mountain Grove, Missouri, by the Missouri State Fruit Experiment Station. Introduced commercially in 1935. Conard × Delicious; selected in 1930. Fruit: large; well colored; uniform in size and shape; quality fair; stems long. Tree: vigorous; leaves large; twigs thick; fruit does not drop when dry weather occurs in early fall.

Wrixparent.— Originated in Magnolia, Delaware, by Wrixhem McIlvaine. Introduced commercially in 1940. Patent no. 388. Open-pollinated seedling of

Transparent; selected in 1915. Fruit: ripens early; large. Most nearly resembles Transparent.

York-A-Red.— Originated in Hedgesville, West Virginia, by Paul L. Lingamfelter. Introduced commercially in 1937. Patent no. 258. Bud mutation of York Imperial; discovered in 1931. Fruit: identical with York Imperial except for allover red color.

Yorking *(Red York Imperial; Red Yorking)*.— Originated in Shippensburg, Pennsylvania, by the Allison Estate. Introduced commercially in 1932. Patent no. 125. Bud mutation of York Imperial; discovered about 1925. Fruit: color all red instead of partly red as on parent tree.

Apricot

Ernie Fehr.— Originated in Lewiston, Idaho, by Emma Marie Fehr. Introduced commercially about 1938. Patent no. 503. Parentage unknown. Fruit: large; matures early; firm; cans well; fine flavor. Tree: quite productive.

Harriet.— Originated in Saint Paul, Minnesota, by Carl Weschcke. Introduced commercially in 1942. Patent no. 476. Parentage unknown; selected about 1933. Fruit: flavor high; matures in August. Tree: hardy.

Perfection.— Originated in Waterville, Washington, by John and Bertha Goldbeck. Introduced commercially in 1937. Parentage unknown; selected from seed planted in 1911. Fruit: large; uniform shape. Tree: hardy.

Riland.— Originated in Rock Island, Washington, by H. Yount. Introduced commercially in 1932. Patent no. 74. Parentage unknown; seed planted in 1923. Fruit: said to keep well.

Avocado

Bonita.— Originated in Homestead, Florida, by C. Santini. Introduced commercially in 1936. Parentage unknown; selected in 1930. Fruit: medium to large; obovate; green; not considered promising for northern United States' markets, but sells well locally; season December and January. Tree: bears heavily. Class "A" for pollination purposes.

Booth 1.— Originated in Homestead, Florida, by William Booth. Introduced commercially in 1935. Open-pollinated seedling of Guatemalan race (probably a West Indian cross); selected in 1927. Fruit: season December and January; withstands cold storage; quality rather poor; seed extremely large. Tree: regular and heavy bearer. Class "A" for pollination purposes.

Booth 3.— Originated in Homestead, Florida, by William Booth. Introduced commercially in 1940. Open-pollinated seedling of Guatemalan race (probably a West Indian cross); selected in 1927. Fruit: quality good; season December and January. Tree: bears heavily. Class "B" for pollination purposes. Most nearly resembles Booth 7.

Booth 7.— Originated in Homestead, Florida, by William Booth. Introduced commercially in 1935. Open-pollinated seedling of Guatemalan race (probably a West Indian cross); selected in 1927. Fruit: flavor good; shape round-obovate; season December and January. Tree: bears prolifically. Class "B" for pollination purposes.

Booth 8.— Originated in Homestead, Florida, by William Booth. Introduced commercially in 1935. Open-pollinated seedling of Guatemalan race (probably a West Indian cross); selected in 1927. Fruit: medium to small; marketing season good (November and December); somewhat resembles Hickson. Tree: very prolific bearer. Class "B" for pollination purposes.

Coit.— Originated in Vista, California, by J. Eliot Coit. Introduced in 1936. Parentage unknown (but from a Guatemalan × Mexican cross); registered with the California Avocado Society in 1939. Fruit: light green; thin skin; smooth, pyriform; 10 to 16 ounces; seed medium; flavor good; oil content 15 per cent; season May to August 1 (southern California); most nearly resembles Fuerte.

Collinson.— Originated in Miami, Florida, by the United States Department of Agriculture Plant Introduction Garden. Introduced commercially in 1922. Collins × unknown (probably of West Indian race); selected in 1920. Fruit: flavor good. Tree: a very poor bearer; pollen sterile. Class "A" for pollination purposes.

Edranol.— Originated in Vista, California, by E. R. Mullen. Introduced commercially in 1932. Open-pollinated seedling of Lyon; selected in 1930. Guatemalan race. Fruit: skin green and thick; pyriform; quality high; flavor excellent; seed small; season early summer. Tree: tall; slender; vigorous; bears heavily.

Fuchsia.— Originated in Homestead, Florida, by C. T. Fuchs, Sr. Introduced commercially in 1926. Open-pollinated seedling of West Indian race; selected in 1916. Fruit: earliest maturing variety (season from late June to August); flavor good; appearance handsome; does not hold up for distant shipping when fully mature or overmature. Class "A" for pollination purposes.

Hall.— Originated in Miami, Florida, by Willis Hall. Introduced commercially in 1938. Parentage unknown (probably a West Indian × Guatemalan hybrid); selected in 1937. Fruit: large; bright green; handsome; season November to March. Tree: alternate but heavy bearer. Resembles Monroe in being excellent for the limited fancy-fruit market. Class "B" for pollination purposes.

Harris.— Originated in Homestead, Florida, by W. K. Walton. Introduced commercially in 1940. Open-pollinated seedling of Wagner; selected in 1935. Fruit: season desirable, from December to February; small to medium; dull, dark green; resembles Booth 7, but has more rippled skin. Tree: heavy bearer. Class "A" for pollination purposes.

Hass.— Originated in La Habra Heights, California, by Rudolph G. Hass. Introduced commercially in 1936. Patent no. 139. Parentage unknown (but of Guatemalan race); selected in 1934. Fruit: flavor excellent; no fiber; oil content 23.7 per cent; size 10 ounces; skin leathery, purple when ripe, thick, rough; seed small; keeping qualities excellent; good shipper. Tree: heavy bearer; starts bearing second year; thrifty grower; buds and grafts readily.

Herman.— Originated in South Miami, Florida, by Fred Herman. Introduced commercially in 1940. Parentage unknown; selected in 1937. Fruit: quality good; season November through January; most nearly resembles Lula, but has smoother skin. Tree: precocious and heavy bearer. Class "A" for pollination purposes.

Hickson.— Originated in Navanja, Florida, by J. R. Hickson. Introduced commercially in 1936. Parentage unknown; selected in 1934. Fruit: flavor excellent; ships well; season desirable, November to January; similar to Booth 8 in shape, but brighter green in color. Tree: fair bearing ability. Class "B" for pollination purposes.

Jalna.— Originated in Vista, California, by J. Eliot Coit. Introduced commercially in 1936. Parentage unknown (but of Mexican race); selected in 1933. Fruit: thin skin; green. Tree: heavy bearer, being one of the few green-fruited Mexican avocados that produces well on the Pacific Coast.

Leucadia.— Originated in Encinitas, California, by J. Eliot Coit. Introduced commercially in 1932. Parentage unknown (but of Mexican type); selected in 1929. Fruit: size good; skin handsome, purple, thin, smooth; most nearly resembles Puebla.

Lindgren.— Originated in Goulds, Florida, by A. Lindgren. Introduced commercially in 1940. Parentage unknown; selected in 1935. Fruit: small; attractive; bright green; season November and December; seed moderately large. Class "A" for pollination purposes.

Lula.— Originated in Miami, Florida, by George B. Cellon. Introduced commercially in 1921. Open-pollinated seedling of Taft (probably crossed with Mexican race); selected in 1919. Fruit: flavor good; very susceptible to avocado scab; pyriform. Tree: prolific and regular bearer. Class "A" for pollination purposes.

Macpherson.— Originated in Encinitas, California, by James H. Macpherson. Introduced commercially in 1942. Patent no. 433. Parentage unknown; selected in 1936. Fruit: appearance and flavor good; skin green, smooth; flesh deep, golden color; seed small; season December to April. Tree: large; vigorous grower.

Monroe.— Originated in Homestead, Florida, by J. J. L. Phillips. Introduced commercially in 1937. Patent no. 261. Parentage unknown (very likely a West Indian × Guatemalan hybrid); selected in 1935. Fruit: large; hand-

some; shiny green; season December and January. Tree: heavy bearer. Class "B" for pollination purposes.

Simpson.—Originated in Richmond, Florida, by Robert Simpson. Introduced commercially in 1933. Parentage unknown (very likely West Indian × Guatemalan hybrid); selected in 1925. Fruit: large, obovate; light green; skin smooth; season November to December. Class "B" for pollination purposes.

Blackberry

Acme Thornless Young.— Originated in Chino, California, by Elmer L. Pollard and Jubal E. Sherrill. Introduced commercially in 1930. Patent no. 4. Bud mutation of Young; discovered in 1928. Plant: thornless; has all the other characteristics of parent, but is more susceptible to disease.

Bauer Thornless Logan.— Originated in San Gabriel, California, by Beulah E. Bauer and Gordon R. Bauer. Introduced commercially in 1934. Patent no. 82. Bud mutation of Logan; discovered in 1929. Plant: canes and leaves entirely thornless; canes strong; season earlier and longer than that of parent.

Brainerd.— Originated in Atlanta, Georgia, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1932. Himalaya × Eastern erect-growing variety (possibly Georgia Mammoth); selected in 1920. Fruit: large; quality high; good for canning, preserving, and the frozen-pack trade. Bush: extremely productive and vigorous; very hardy.

Cascade.— Originated in Corvallis, Oregon, by the United States Department of Agriculture (George M. Darrow and George F. Waldo). Introduced commercially in 1940. Zielinski × Logan; selected in 1935. Fruit: excellent for canning or in frozen pack; flavor characteristic of the native blackberry *(Rubus macropetalus)*. Bush: vigorous and productive.

Pacific.— Originated in Corvallis, Oregon, by the United States Department of Agriculture (George M. Darrow and George F. Waldo). Introduced commercially in 1940. Zielinski × Logan; selected in 1935. Fruit: excellent for canning and frozen pack; firmer than Cascade, and with more acid; flavor characteristic of the native blackberry *(Rubus macropetalus)*. Bush: vigorous and productive.

Thornless Boysen.— Originated in El Monte, California, by D. L. Duffin. Introduced commercially in 1938. Bud mutation of Boysen; discovered in 1936. May be identical with Acme Thornless Young.

Blueberry

Atlantic.— Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1941. Jersey × Pioneer; selected in 1925. Fruit: flavor good; size superior; no cracking in wet weather; ripens late.

Burlington.— Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1941. Rubel × Pioneer; selected in 1916. Fruit: matures late; dessert quality very good. Bush: vigorous; healthy.

Pemberton.— Originated in Whitesbog, New Jersey, by the United States Department of Agriculture (F. V. Coville). Introduced commercially in 1941. Katharine × Rubel; selected in 1921. Fruit: matures late; large. Bush: very productive; extremely vigorous.

Butternut

Weschcke.— Originated in River Falls, Wisconsin, by Carl Weschcke. Introduced commercially in 1938. Open-pollinated seedling of a wild tree; discovered about 1934. Nut: claimed to crack out in whole halves. Tree: hardy.

Carissa

Chesley.— Originated in Carlsbad, California, by Chesley Alles. Introduced in 1929. Parentage unknown; selected in 1928. Fruit: size large; flavor and texture not too good.

Serena.— Originated in Santa Barbara, California, by J. Eliot Coit. Introduced commercially in 1932. Parentage unknown; selected in 1929. Fruit: ripe 8 months of the year; stem long, making it possible to pick with buttons on; good keeper.

Cherimoya

Ryerson.— Originated in Chula Vista, California, by William H. Sallman. Selected in 1928 by J. Eliot Coit, who named it for Knowles A. Ryerson. Introduced commercially in 1935. Parentage unknown. Fruit: shape regular; skin smooth and tough; ships well.

Cherry

Early Montmorency.— See **Richmorency.**

Montearly.— Originated in East Jordan, Michigan, by Levi R. Taft. Introduced commercially in 1932. Patent no. 30. Parentage unknown; selected in 1928. Fruit: sour; one-third larger than Early Richmond; ripens 10 days to 2 weeks earlier than Montmorency, which it resembles.

Montlate.— Originated in East Jordan, Michigan, by Levi R. Taft. Introduced commercially in 1932. Patent no. 29. Mutation of Montmorency; selected in 1927. Fruit: sour; identical with Montmorency except that it ripens 10 days to 2 weeks later than parent.

Rainbow Stripe.— Originated in Yakima, Washington, by E. Remy & Son. Introduced commercially in 1930. Bud mutation of Lambert; discovered in 1925. Fruit: sweet; white with a narrow blood-red stripe from stem to tip, extending through the flesh; most nearly resembles Lambert.

Richmorency *(Early Montmorency).*— Originated in Saint Joseph, Michigan, by L. B. Reber. Introduced commercially in 1938. Patent no. 316. Bud mutation of Montmorency; discovered in 1929. Fruit: ripens 1 week or more before parent; sour.

Sweet September.— Originated in Wayne County, Ohio, by Menno Gerber. Introduced commercially in 1936. Patent no. 94. Parentage unknown; selected in 1930. Fruit: sweet; ripens latter part of August; keeps in good condition on tree for a long time.

Velvet.— Originated in Vineland, Ontario, Canada, by Ontario Horticultural Experiment Station. Introduced commercially in 1937. Open-pollinated seedling of Windsor; selected in 1925. Fruit: sweet; black; ripens late; best variety in Station quick-freezing tests. Most nearly resembles Schmidt.

Vernon.— Originated in Vineland, Ontario, Canada, at the Ontario Horticultural Experiment Station. Introduced commercially in 1937. Open-pollinated seedling of Windsor; selected in 1925. Fruit: sweet; black; ripens in midseason; quality good; firm. Tree: yields heavy crops. Most nearly resembles Windsor.

Victor.— Originated in Vineland, Ontario, Canada, at the Ontario Horticultural Experiment Station. Introduced commercially in 1925. Open-pollinated seedling of Windsor; selected in 1923 from 1916 crosses. Fruit: sweet; ripens early; white, heavily blushed, therefore outsells Napoleon (Royal Ann); processes well. Most nearly resembles Napoleon.

Filbert

Bixby *(Jones No. 200).*— Originated in Lancaster, Pennsylvania, by J. F. Jones. Introduced commercially in 1937. Rush *(Corylus americana)* × Italian Red *(C. avellana)*; tree first bore in 1924. Nut: appearance attractive; kernels clean and sweet. Tree: very hardy; prolific.

Carlola.— Originated in River Falls, Wisconsin, by Carl Weschcke. Introduced commercially in 1941. *Corylus americana* × Brag. Nut: matures early; shell very thin; large. Tree: very prolific; resistant to wild hazel blight.

Dolores.—Originated in River Falls, Wisconsin, by Carl Weschcke. Introduced commercially in 1941. *Corylus americana* × Brag. Nut: kernel has very thin pellicle; light-colored meats; shell thin, matures early.

Jones No. 200.— See **Bixby.**

Magdalene.— Originated in River Falls, Wisconsin, by Carl Weschcke. Introduced commercially in 1941. *Corylus americana* × Brag. Nut: matures early; thin shell; large.

Nonpareil.— Originated in Washougal, Washington, by D. Fitzgerald. Introduced commercially in 1938. Parentage unknown. Nut: kernel white; round type.

Woodford.— Originated in Forest Grove, Oregon, by E. W. Woodford. Introduced commercially in 1936. Parentage unknown. Tree: pollinizer for Barcelona.

Gooseberry

Glendale.— Originated in Little Silver, New Jersey, by the United States Department of Agriculture (Walter Van Fleet). Introduced commercially in 1932. [(*Grossularia missouriensis* × Red Warrington) × Triumph] × Keepsake; selected in 1905. Fruit: excellent for jam; seeds small. Plant: vigorous; best for southern limit of gooseberry growing.

Grape

Empress *(Seedless Emperor).*— Originated in Visalia, California, by Vahan Mkhalian. Introduced commercially in 1939. Patent no. 311. Bud mutation of Emperor; discovered in 1928. Fruit: seedless, but retains characteristics of parent; berry much smaller than parent.

La Pryor.— Originated in La Pryor, Texas, by the Texas Agricultural Experiment Station. Introduced commercially in 1934. Parentage unknown, probably *Vitis candicans* × *V. rupestris* hybrid; discovered in 1933. Fruit: size medium; sweet; black; clusters small; light producer. Valuable for rootstock purposes only.

Sanger Sweet.— Originated in Sanger, California, by E. L. Magnone. Introduced commercially in 1942. Patent no. 509. Open-pollinated seedling of Muscat of Alexandria; selected about 1924. Fruit: sweet, with a Muscat flavor; firm; good shipper; seedless.

Seedless Emperor.— See **Empress.**

Grapefruit

John Garner.—Originated in Texas by George W. Baylor. Introduced commercially in 1934. Open-pollinated seedling of Duncan. Fruit: size similar to Duncan; nearly seedless; ripens about 2 weeks later than Duncan; quality good.

Guava

Redland.— Originated in Homestead, Florida, by the Florida Subtropical Experiment Station (S. J. Lynch and H. S. Wolfe). Introduced commercially in 1941. Parentage unknown; seed obtained from Atkins Institute, Arnold Arboretum, Cuba; selected in 1938. Fruit: large; pyriform; no musky guava odor; flavor mild; matures in winter. Tree: heavy cropper; susceptible to red algae spot.

Hickory

Weschcke.—Originated in Fayette, Iowa, by Carl Weschcke. Introduced commercially in 1936. Unknown seedling of shagbark; selected about 1928. Nut: matures September 1 to 15; papershell; kernel full and rich, cracking out in entire halves. Grafts well on wild bitternut hickory *(Carya cordiformis).*

Mandarin

Kara.— Originated in Riverside, California, by the California Citrus Experiment Station (H. B. Frost). Introduced commercially in 1935. Owari (?) Satsuma × King; selected in 1925. Fruit: size good; quality excellent; high in sugar and acid; flesh color high; aroma unique.

Kinnow.— Originated in Riverside, California, by the California Citrus Experiment Station (H. B. Frost). Introduced commercially in 1935. King × Willow Leaf; selected in 1925. Fruit: matures early; quality and appearance excellent; sugar very high; as acid as the sweet orange; aroma unique.

Wilking.— Originated in Riverside, California, by the California Citrus Experiment Station (H. B. Frost). Introduced commercially in 1935. King × Willow Leaf; selected in 1925. Fruit: flavor very good; maintains firmness in a long season. Not valuable unless the excessive alternate bearing, now usual at Riverside, California, can be obviated.

Mango

Brooks *(Brooks Late)*.— Originated in Miami, Florida, by the Charles Deering Estate. Introduced commercially in 1924. Open-pollinated seedling of Sandersha; selected in 1916. Fruit: quality fair; not particularly attractive, but late in season (August to October). Tree: weak growing; heavy bearer.

Brooks Late.— See **Brooks**.

Fascell.— Originated in Miami, Florida, by Michael Fascell. Introduced commercially in 1942. Patent no. 451. Brooks × Haden (?); selected in 1936. Fruit: ovate, compressed laterally; 250 to 500 grams; pale yellow to dark carmine blush; ships well; quality good. Tree: bears heavily and regularly. Seems resistant to anthracnose.

Fragrance.— Originated in Naples, Florida, by E. G. Wilkinson. Introduced commercially in 1938. Patent no. 119. Open-pollinated seedling of Mulgoba. Fruit: excellent flavor; long season.

Schobank.— Originated in Schofield Barracks, Hawaii, by the Board of Commissioners of Agriculture and Forestry. Introduced commercially in 1941. Open-pollinated seedling of Pirie (Paheri); selected in 1940. Plant: bears at high elevation where rain does not affect blossoms; heavy bearer.

Simmonds.— Originated in Coconut Grove, Florida, by Edward Simmonds. Introduced commercially in 1942. Haden × Carabao; selected in 1934. Fruit: ovate to oblong-ovate; 375 to 525 grams; season July and August, slightly later than Haden; quality fair; fibers few. Tree: bears heavily.

Springfels.— Originated in West Palm Beach, Florida, by Charles Springfels. Introduced commercially in 1930. Open-pollinated seedling of Haden; selected in 1925. Fruit: oblong; large; 600 to 900 grams; quality fair to good; small amount of fiber; orange yellow with maroon to crimson cheek; season July and August; ships well. Tree: bears heavily.

Natal Plum

(See Carissa)

Nectarine

Kim.— Originated in Merced, California, by F. W. Anderson. Introduced commercially in 1938. Patent no. 173. J. H. Hale × Lippiatt, from F_2; selected in 1935. Fruit: yellow-fleshed freestone; firm; high color; ripens with Gower.

Le Grand.— Originated in Le Grand, California, by F. W. Anderson. Introduced commercially in 1942. Patent no. 549. J. H. Hale × Quetta, from F_2; selected in 1936. Fruit: yellow-fleshed clingstone; large; firm.

Sequoia.— Originated in Porterville, California, by F. D. Williams. Introduced commercially in 1942. Patent no. 496. Bud mutation of Hutchison peach; discovered in 1937. Fruit: large; skin smooth with deep red color; ripens late. Tree: bears well.

Tioga.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1941. (Salwey × Quetta) × Lippiatt: Fruit: yellow-fleshed freestone; late; firm until fully mature; quality good; good for frozen pack.

Orange

Trovita.— Originated in Riverside, California, by the California Citrus Experiment Station (H. B. Frost). Introduced commercially in 1935. Perhaps open-pollinated seedling of Washington Navel; selected in 1928. Fruit: matures very early; more juicy than Washington Navel. Tree: very productive. Most nearly resembles Washington Navel orange.

Peach

All-Red-Free.— See **Erly-Red-Fre**.

Amador.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in

1942. Elberta × Ontario. Fruit: ripens early midseason; appearance attractive; quality excellent; freestone. Tree: somewhat resistant to delayed foliation.

Andora.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1941. Libbee × Lovell. Fruit: quality good; ripens in early midseason with Peak; commercial canning clingstone.

Babcock.— Originated in Riverside, California, by the California Citrus Experiment Station (E. B. Babcock, H. B. Frost, J. W. Lesley). Introduced commercially in 1933. F_2 of (Strawberry × Peento); selected in 1923. Fruit: freestone; flesh white; high blush; rather small. Tree: requires little winter chilling.

Bates.— Originated in Delhi, California, by W. H. Bates. Introduced commercially in 1939. Patent no. 604. Parentage unknown; selected in 1935. Fruit: ripens in Phillips Cling season; commercial canning clingstone.

Bonita.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1943. Rosy × Golden State; selected in 1940. Fruit: yellow-fleshed freestone. Tree: requires very little winter chilling.

Carolyn.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1942. Libbee × Lovell. Fruit: quality good; commercial canning clingstone; ripens between seasons of Gaume and Sims. Tree produces heavily.

Chaffey.— Originated in Ontario, California, by Chaffey Junior College (George P. Weldon). Introduced commercially in 1939. Lukens Honey × Elberta. Fruit: solid, white-fleshed freestone; quality excellent; semisweet. Tree: fairly resistant to delayed foliation; dependable producer; vigorous.

Christensen Early Elberta.— Originated in Brigham City, Utah, by C. W. Christensen. Introduced commercially in 1929. Open-pollinated seedling of Elberta; selected about 1920. Fruit: ripens 2 to 3 weeks earlier than known parent; high skin color; flesh red at center; ships well. Tree: buds only moderately hardy.

Corona.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1942. Libbee × Lovell. Fruit: large; commercial canning clingstone; late (after Phillips Cling by 3 to 4 days); quality good. Tree: heavy producer.

Cortez.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1944. Paloro × Halford No. 1. Fruit: ripens in the early part of the canning clingstone season.

C. O. Smith.— Originated in Whittier, California, by the California Agricultural Experiment Station (E. B. Babcock and C. O. Smith). Introduced commercially in 1933. F_2 of (Strawberry × Peento); selected in 1930. Fruit: similar to Lukens Honey, but much larger; too soft for a commercial variety; recommended highly for home use in southern California. Tree: resistant to delayed foliation; vigorous; heavy producer.

Early Halehaven.— Originated in Benton Harbor, Michigan, by John Nametz. Introduced commercially in 1939. Patent no. 325. Bud mutation of Halehaven; discovered in 1935. Fruit: ripens 7 to 10 days before Halehaven; in other characteristics similar to parent.

Early Rochester.— Originated in Yakima, Washington, by V. C. Campbell. Introduced commercially in 1940. Patent no. 351. Open-pollinated seedling of Rochester; selected about 1932. Fruit: clingstone; ripens 18 to 21 days earlier than Rochester; in other characteristics similar to Rochester.

Ellis.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1935. Phillips Cling × Linden. Fruit: ripens in late midseason; commercial canning clingstone.

Erly-Red-Fre *(All-Red-Free)*.— Originated in Chase City, Virginia, by W. M. Perry. Introduced commercially in 1938. Patent no. 320. Parentage unknown; discovered in 1936. Fruit: color all red; freestone; larger than Red Bird; ripens in Red Bird season; skin thick; seed small.

Farida.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1938. Leader seedling 26–13 (clingstone) × (Paloro × Tuscan). Fruit: ripens early (Tuscan season); clingstone; recommended especially as an early shipping clingstone, but may be canned.

Fertile Hale.— Originated in Lawrence, Michigan, by Lawrence La Duke. Introduced commercially in 1935. Patent no. 175. Bud mutation of J. H. Hale; discovered in 1927. Fruit: size of J. H. Hale. Flowers: self-fertile. Tree: vigorous; more hardy than parent or Elberta.

Fontana.— Originated in Ontario, California, by Chaffey Junior College (George P. Weldon). Introduced commercially in 1939. Sims × (Feicheng × Bolivian Cling). Fruit: clingstone; pit small; excellent canner; hangs well on tree; deep yellow flesh even when skin still appears green. Tree: more resistant to delayed foliation than Sims; good producer. Most nearly resembles Sims.

Fortuna.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1941. Leader seedling (clingstone) × (Tuscan × Paloro). Fruit: quality good; ripens early (Tuscan season or earlier); commercial canning clingstone. Tree: heavy producer.

Glamar.— Originated in Osoyoos, British Columbia, Canada, by J. S. Leekie. Introduced commercially in 1942. Patent no. 592. Bud mutation of Rochester; selected in 1939. Fruit: ripens 3 weeks earlier than parent; in most other characteristics same as Rochester.

Golden State.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1942. Paragon × F_2 seedling (Elberta × Peento); selected in 1933. Fruit: freestone; yellow; firm. Tree: requires little winter chilling.

Gomes.— Originated in Modesto, California, by Felix Gomes. Introduced commercially in 1936. Parentage unknown; selected in 1935. Fruit: ripens in late Phillips Cling season; commercial canning clingstone. Most nearly resembles Stuart.

Halehaven.— Originated in South Haven, Michigan, by the Michigan (South Haven) Agricultural Experiment Station. Introduced commercially in 1932. J. H. Hale × South Haven; cross made in 1924. Fruit: color high; flesh firm enough for commercial handling; freestone; quality excellent; use fresh or canned; most nearly resembles South Haven, but firmer and with better color.

Halford No. 2.— Originated in Modesto, California, by John Halford. Introduced commercially in 1921. Parentage unknown; discovered in 1919. Fruit: commercial canning clingstone; produces heavy crops of fruit with excellent canning quality.

Halo.— Originated in Clarkston, Washington, by H. Lynn Tuttle. Introduced commercially in 1942. Open-pollinated seedling of Tuscan (Tuskena); selected about 1936. Fruit: freestone; very high color 1 or 2 weeks before ripening; size good; flavor excellent. Tree: resistant to spring frosts; bears early and heavily.

Hermosa.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1942. J. H. Hale × Babcock; selected in 1937. Fruit: appearance attractive; flesh white; freestone. Tree: requires little winter chilling.

Hoffman.— Originated in Live Oak, California, by Phillip B. Hoffman. Introduced commercially in 1937. Patent no. 593. Parentage unknown; selected in 1935. Fruit: commercial canning clingstone; ripens in Phillips Cling season. Leaves: glandless.

Howard Fisher.— Originated in Queenston, Ontario, Canada, by C. Howard Fisher. Introduced commercially in 1936. Patent no. 233. Bud mutation of Valiant; discovered in 1934. Fruit: ripens early; large; flavor very fine; butter-yellow with bright red blush; good shipper; will not drop from tree even when fully ripe; semifreestone. Most nearly resembles Valiant.

Hutchison.— Originated in Woodville, California, by Perry Hutchison. Introduced commercially in 1938. Parentage unknown; selected in 1934. Fruit: large; texture smooth; ripens well when picked hard; good for frozen pack. Tree: vigorous.

Johnson Early Elberta.— Originated in Brigham City, Utah. Introduced commercially in 1935. Parentage unknown (but probably an open-pollinated seedling of Elberta or Early Elberta); selected in 1922. Fruit: ripens with Early Elberta; firmer and better color than Early Elberta. Tree: very hardy; buds only moderately hardy.

Kalhaven.— Originated in South Haven, Michigan, by the Michigan (South Haven) Agricultural Experiment Station. Introduced commercially in 1936. J. H. Hale × Kalamazoo; cross made in 1924. Fruit: matures 4 to 7 days before Elberta, helping to fill in the season between Halehaven and Elberta; firm; ships well; quality excellent; most nearly resembles J. H. Hale, but smaller in size.

Klondyke Early Elberta.— Originated in Tremonton, Utah. Introduced commercially in 1930. Parentage unknown; discovered in 1925. Fruit: ripens in Early Elberta season; high color; flesh firm; good shipping quality; dessert quality good. Tree: vigorous; productive; moderately hardy.

Lawrence.— Originated in Puyallup, Washington, by Alex Lawrence. Introduced commercially in 1941. Parentage unknown. Fruit: semifreestone; resembles Rochester in fruit characteristics and quality, but ripens 2 weeks earlier. Tree: bears early and regularly; hardy to spring frosts.

Leeton.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1935. Open-pollinated seedling of Leader. Fruit: early (Triumph season); yellow-fleshed, semiclingstone; dessert type.

Lovell Cling.— See **Wiser.**

Maxine.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1935. No. 1 Late (Michigan Station number) × Lemon Free. Cross made at Michigan Agricultural Experiment Station; seedling fruited in California. Fruit: lemon-yellow; freestone; early midseason. Tree: very heavy producer.

Nectar.— Originated in Bakersfield, California, by Oliver P. Blackburn. Introduced commercially in 1935. Patent no. 86. Parentage unknown (probably Early Wheeler × Stanwick). Fruit: freestone; very large; ripens early; sweet with nectarine flavor. Tree: bears regularly; growth vigorous; foliage heavy. Most nearly resembles Red Bird.

Nestor.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1938. Muir × Paloro. Fruit: freestone; drying use.

Pedersen.— Originated in Modesto, California, by L. E. Pedersen. Introduced commercially in 1937. Parentage unknown; selected in 1935. Fruit ripens in Phillips Cling season; commercial canning clingstone.

Penryn.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1938. Maxine × Leader. Fruit: ripens early; quality good; appearance attractive; a dessert variety; freestone.

Plantz.— Originated in Marysville, California, by William Plantz. Introduced commercially in 1936. Patent no. 262. Parentage unknown; selected in 1935. Fruit: ripens in Phillips Cling season: commercial canning clingstone.

Pomeroy.— Originated in Merced, California, by the California Packing Corporation. Introduced commercially in 1934. Parentage unknown. Selected in 1932. Fruit: ripens in Peak season; commercial canning clingstone.

Ramona.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1943. F_2 seedling of Peak × P. I. 32374; selected in 1933. Fruit: nonmelting, yellow-fleshed clingstone. Tree: requires little winter chilling.

Redelberta.— Originated in Kennewick, Washington, by Jay Perry. Introduced commercially in 1936. Patent no. 232. Bud mutation of Elberta; discovered in 1928. Fruit: ripens 10 days earlier than Elberta; more highly colored than parent; smaller than Elberta.

Redhaven.— Originated in South Haven, Michigan, at the Michigan (South Haven) Agricultural Experiment Station. Introduced commercially in 1940. Halehaven × Kalhaven; cross made in 1930. Fruit: season very early, 30 days before Elberta; flesh very firm, permitting commercial handling and shipping; color brilliant red; freestone.

Redwing.— Originated in Ontario, California, by Walter E. Lammerts. Introduced commercially in 1944. Patent no. 621. Babcock × Stensgaard July Elberta; selected in 1939. Fruit: matures early; large; good blend of sugar and acid; skin color excellent. Resistant to delayed foliation, having a short chilling requirement. Most nearly resembles Babcock.

Rio Oso Gem.— Originated in Rio Oso, California, by W. F. Yerkes. Introduced commercially in 1933. Patent no. 84. Parentage unknown; selected in 1926. Fruit: ripens later than J. H. Hale, extending that season; more highly colored than J. H. Hale, which it most nearly resembles. Self-fruitful.

Robin.— Originated in Ontario, California, by Walter E. Lammerts. Introduced commercially in 1944. Patent no. 529. Babcock × Mayflower; selected in 1941. Fruit: ripens very early, June 1 to 10; skin color excellent; flavor good, sweet with acid blend; larger than Mayflower; semiclingstone.

Rosy.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1942. J. H. Hale × Columbiana-Peento-Elberta hybrid; selected in 1935. Fruit: large; flesh white; freestone. Tree: little winter chilling required.

Shannon.— Originated in Modesto, California, by the Hume Cannery. Introduced commercially in 1939. Parentage unknown; selected in 1935. Fruit: ripens in Phillips Cling season; commercial canning clingstone.

Sharon.— Originated in McFarland, California, by R. E. Armantrout and E. W. Root. Introduced commercially in 1943. Patent no. 540. Parentage unknown; selected in 1930. Fruit: firm, white freestone; flavor distinctive; at McFarland, California, ripens August 15 to 30.

Shasta.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1941. Leader seedling (clingstone) × (Tuscan × Paloro). Fruit: quality good; ripens early (Tuscan season or earlier); commercial canning clingstone. Tree: heavy producer.

South Haven *(Sun Glo)*.— Originated in South Haven, Michigan, by A. G. Spencer. Introduced commercially in 1920. Bud mutation of St. John; discovered in 1911. Fruit: large; very firm; much more productive than other yellow freestones. Became a commercial variety quickly, but is now being replaced by Halehaven. Most nearly resembles Crawford type.

Stanford.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1935. Hauss × Phillips Cling. Fruit: ripens in late midseason (Halford No. 2 season or slightly later); commercial canning clingstone; quality good; hangs well on tree. Tree: heavy producer.

Stuart.— Originated in French Camp, California, by J. F. Stuart. Introduced commercially in 1927. Open-pollinated seedling of Lovell; selected in 1925. Fruit: commercial canning clingstone; ripens in Phillips Cling season; most nearly resembles Gomes.

Sullivan No. 1.— Originated in Tudor, California, by C. E. Sullivan. Introduced commercially in 1936. Patent no. 186. Parentage unknown; selected in 1928. Fruit: ripens in late midsummer season; commercial canning clingstone. Resembles Johnson, a cling.

Sullivan No. 4.— Originated in Tudor, California, by C. E. Sullivan. Introduced commercially in 1940. Parentage unknown; selected in 1929. Fruit: ripens in Phillips Cling season; commercial canning clingstone.

Sunday *(Sunday Elberta)*.— Originated in Baroda, Michigan, by George P. Sunday. Introduced commercially in 1940. Patent no. 418. Parentage unknown; selected in 1927. Fruit: shape similar to Elberta; color, firmness, and quality similar to J. H. Hale; pubescence little; ripens 1 week or more after Elberta. Tree: very hardy.

Sunday Elberta.— See **Sunday.**

Sun Glo.— See **South Haven.**

Sunglow.— Originated in Riverside, California, by the California Citrus Experiment Station (J. W. Lesley). Introduced commercially in 1942. F_2 of J. H. Hale × seedling of Bolivian Cling; selected in 1936. Fruit: freestone; flesh yellow; quality good. Tree: little winter chilling required.

Sungold.— Originated in Des Moines, Iowa, by W. H. Kirsten. Introduced commercially in 1936. Parentage unknown; selected about 1928. Fruit: freestone; flesh yellow; flavor fine; large; ripens 1 week earlier than Elberta; most nearly resembles J. H. Hale. Tree: productive.

Taylor.— Originated in Placer County, California, by E. G. Taylor. Introduced commercially in 1936. Parentage unknown; selected in 1930. Fruit: ripens in Phillips Cling season; commercial canning clingstone. Leaves: glandless.

Tudor.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1941. Libbee × Newkom. Fruit: ripens in midseason (Gaume to Sims season); canning clingstone of best quality. Tree: heavy producer.

Valiant.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1925. Open-pollinated seedling of Elberta; selected in 1922 from 1917 pollination. Fruit: yellow-fleshed freestone; Elberta type but rounder, better quality, and matures 2½ weeks earlier than known parent.

Vanguard.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1941. Vaughan × Valiant; selected in 1930 from 1925 pollination. Fruit: ripens 6 weeks before Elberta and 5 days after June Elberta; yellow-fleshed freestone; quality and appearance good. Most nearly resembles Valiant.

Vaughan.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1925. Leamington × self; selected in 1919 from 1913 pollination. Fruit: yellow-fleshed freestone; appearance dullish; ripens early. Tree: unusually hardy in fruit bud. Most nearly resembles Rochester.

Vedette.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1925. Open-pollinated seedling of Elberta; selected in 1921 from 1915 pollinations. Fruit: flesh yellow; normally freestone, in some seasons semifree only; Elberta type, but fuller, better quality, and matures 3 weeks earlier than Elberta.

Veefreeze.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1940. Ontario No. 11041 (Elberta × open) × Arp Beauty; selected in 1926 from 1920 pollinations. Fruit: yellow-fleshed freestone; retains full peach flavor in frozen pack; exposed flesh (fresh) does not oxidize or brown for hours after being cut. Most nearly resembles Elberta.

Veteran.— Originated in Vineland, Ontario, Canada, at the Ontario Horticultural Experiment Station. Introduced commercially in 1928. Vaughan × Starks Early Elberta; selected in 1925 from 1919 breeding. Fruit: flesh yellow; semifreestone to full freestone; Elberta type, but matures 8 to 10 days before Elberta.

Viceroy.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1929. Vaughan × Starks Early Elberta; selected in 1925 from 1919 breeding. Fruit: yellow-fleshed freestone; Elberta type, but fuller, better quality, and matures 3 weeks earlier than Elberta. Tree: hardy.

Weldon.— Originated in Ontario, California, by Chaffey Junior College (George P. Weldon). Introduced commercially in 1939. Babcock × [Elberta × (Elberta × Peento)]. Fruit: quality good; precedes Elberta in ripening; freestone. Tree: highly resistant to delayed foliation; dependable producer.

Williams.— Originated in Merced, California, by the California Packing Corporation. Introduced commercially about 1936. Parentage unknown; selected about 1932. Fruit: ripens in Halford No. 2 time; commercial canning clingstone.

Wiser *(Lovell Cling).*— Originated in Gridley, California, by Ray B. Wiser. Introduced commercially in 1943. Patent no. 507. Sims × Lovell; selected in 1933. Fruit: commercial canning clingstone; ripens in Phillips Cling season; free from red at pit. Tree: growth willowy and vigorous; bears heavily. Most nearly resembles Lovell.

Pecan

Brake.— Originated in Rocky Mount, North Carolina, by H. L. Brake. Introduced commercially in 1937. Parentage unknown; seed planted in 1910. Patent no. 47. Nut: shell extremely thin; high kernel percentage; easily shelled; shorter and smaller than Schley. Tree: hardy; resistant to disease, especially scab.

Humble.— Originated in Zavalla County, Texas, by J. A. Simpson. Introduced commercially in 1933. Patent no. 73. Parentage unknown. Tree: bears heavily and regularly; pronounced precocity; growth vigorous; wide range of adaptability; immune to disease and insects; relatively little chilling requirement.

Plum

(See also Prune.)

Crystal Red.— Originated in North Grimsby, Ontario, Canada, by A. W. Eickmeier. Introduced commercially in 1943. Patent no. 560. Parentage unknown, but of Japanese type; selected in 1940. Fruit: matures 2 to 3 weeks earlier than Burbank, which it resembles; highly colored; excellent shipper. Tree: regular and early bearer; strong grower; upright spreading; hardy.

Padre.— Originated in Palo Alto, California, by the United States Department of Agriculture (W. F. Wight). Introduced commercially in 1938. Wickson × Santa Rosa. Fruit: early shipping plum, slightly later than Santa Rosa. Japanese type.

Pomegranate

Trauernicht.— Originated in Forth Worth, Texas, by E. C. Trauernicht. Introduced commercially in 1936. Patent no. 184. Parentage unknown; selected in 1934. Plant: flowers all summer; produces heavily; semidwarf; hardy.

Prune

Gardner.— Originated in Corvallis, Oregon, by the Oregon Agricultural Experiment Station. Introduced commercially in 1923. Petite d'Agen (French) × self; selected in 1923. Fruit: sugar content high; perhaps not superior to Petite d'Agen. Tree: heavy producer.

Richards Early Italian.— Originated in Wapato, Washington, by E. C. Richards. Introduced commercially in 1935. Parentage unknown; selected in 1930. Fruit: ripens 3 days before Demaris. Most nearly resembles Italian.

Raspberry

Milton.— Originated in Geneva, New York, by the New York State Agricultural Experiment Station. Introduced commercially in 1942. Lloyd George × Newburgh; cross made in 1927. Fruit: bright red; large; firm; quality good; ripens late; most nearly resembles Taylor. Plant: vigorous; productive; escapes mosaic.

Potomac.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1933. Farmer black raspberry × Newman red raspberry; selected in 1924. Fruit: purple; well suited for canning and preserving. Bush: resistant to fungus disease; free from virus diseases; vigorous; productive.

Tahoma.— Originated in Puyallup, Washington, at the Western Washington Experiment Station. Introduced commercially in 1938. Latham × Lloyd George; selected in 1935. Fruit: red; ripens very early; shipping quality good. Plant: hardy; escapes mosaic infection; resistant to western yellow rust.

Tennessee Autumn *(Tennessee No. Y944).*— Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station. Introduced commercially in 1940. Patent no. 512. Tennessee Seedling 181 × Lloyd George;

selected in 1935. Fruit: red; quality good. Plants: healthy; production heavy; some southern adaptation; two-cropper.

Tennessee No. Y944.— See **Tennessee Autumn.**

Van Fleet.— Originated in Chico, California, by the United States Department of Agriculture (Walter Van Fleet). Introduced commercially in 1924. *Rubus kuntzeanus* × Cuthbert; selected in 1911. Female parent collected in China. Fruit: red. Plant: very vigorous; highly productive; resistant and hardy in southern states where other raspberry plants do not succeed.

Viking.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1924. Cuthbert × Marlboro; selected in 1918 from 1914 breeding. Fruit: red; ripens in early midseason; large, bright, good market berry; easily picked. Most nearly resembles Cuthbert.

Washington.— Originated in Puyallup, Washington, at the Western Washington Experiment Station. Introduced commercially in 1938. Cuthbert × Lloyd George; selected in 1935. Fruit: red; quality high; canning and freezing adaptability. Plant: definite rest period; production heavy; escapes mosaic infection; resistant to western yellow rust.

Willamette.— Originated in Corvallis, Oregon, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1943. Newburgh × Lloyd George; selected in 1936. Fruit: red; large; excellent for shipping; firm; most nearly resembles Newburgh, but fruit is darker.

Sapote, White

(See White Sapote.)

Strawberry

Alamo *(Texas No. 21).*— Originated in Texas by the Texas Agricultural Experiment Station. Introduced commercially in 1937. Blakemore × Ettersburg 80?; selected in 1935. Fruit: flavor mild. Plant: yields heavily; large; low plant producer.

Bellmar.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1932. Missionary × Howard 17; selected in 1925. Fruit: firm; high dessert and shipping quality.

Blakemore.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1930. Missionary × Howard 17; selected in 1925. Fruit: matures early; good color; skin tough; firm; flavor tart and excellent; very good for preserving. Adapted to southern states.

Branford *(Connecticut 431).*— Originated in New Haven, Connecticut, by the Connecticut Agricultural Experiment Station (D. F. Jones). Introduced commercially in 1939. (Kalicene × Howard 17) × (Progressive × Howard 17); first selected in 1923. Fruit: color light and bright, being excellent in frozen product and in preserves; size and shape even.

Brightmore.— Originated in Corvallis, Oregon, by the United States Department of Agriculture (George M. Darrow and George F. Waldo). Introduced commercially in 1942. Blakemore × Oregon 154; selected in 1934. Fruit: quality excellent for frozen pack; bright red; most nearly resembles Blakemore. Plant: fairly resistant to virus diseases.

Bristol.— Originated in New Haven, Connecticut, by the Connecticut Agricultural Experiment Station (D. F. Jones). Introduced commercially in 1939. (Chesapeake × Marshall) × (Progressive × Howard 17); selected in 1923. Fruit: attractive; quality high. Most nearly resembles Chesapeake.

Connecticut 431.— See **Branford.**

Corvallis *(Oregon State College 12).*— Originated in Oregon by the Oregon Agricultural Experiment Station (C. E. Schuster). Introduced commercially in 1930. Ettersburg 121 × Marshall; selected in 1922. Fruit: excellent for canning and frozen pack. Plant: vigorous and very productive. Most nearly resembles Ettersburg 121.

Crimson Glow *(New Jersey 311).*— Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (J. H. Clark).

Introduced under restrictions in 1940; named in 1943. Fairfax × New Jersey 51 (Pearl × Aberdeen); selected in 1933. Fruit: quality high; picking easy, since stem breaks back of calyx.

Daybreak.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1939. Missionary × Fairfax; selected in 1932. Fruit: matures early; large. Bush: very vigorous; crop large.

Dorsett.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1933. Royal Sovereign × Howard 17; selected in 1925. Fruit: dessert quality high; appearance attractive. Bush: very vigorous and productive.

Eleanor Roosevelt.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1939. Bellmar × Fairfax; selected in 1933. Fruit: immense; firm; deep red; season long; shipping quality good. Bush: very productive.

Fairfax.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1933. Royal Sovereign × Howard 17; selected in 1925. Fruit: exceptional firmness; dessert quality high; appearance fine; season early and long; large.

Fairmore.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1939. Blakemore × Fairfax; selected in 1934. Fruit: very firm; shipping quality high; season early; flavor high in southern states. Bush: vigorous growth.

Hebron.— Originated in New Haven, Connecticut, by the Connecticut Agricultural Experiment Station (D. F. Jones). Introduced commercially in 1939. Inbred Chesapeake × (F_1 cross of inbred Progressive × Howard 17). Fruit: matures late; color light, bright; calyces green on maturing. Most nearly resembles Chesapeake.

Improved Clark *(Ulrich)*.— Originated near The Dalles, Oregon, by Julius Ulrich. Introduced commercially in 1925. Plant found near a field containing Gold Dollar and Clark; discovered in 1920. Plant: seems resistant to strawberry mite in Hood River Valley. Most nearly resembles Clark's Seedling.

Julymorn *(New Jersey 225)*.— Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (J. H. Clark). Introduced under restrictions in 1938; named in 1943. Redheart × New Jersey 5 (Mastodon × Howard 17); selected in 1932. Fruit: very firm; strong inside color; good for processing; most nearly resembles Redheart.

McClintock *(Tennessee No. 6)*.— Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station. Introduced commercially in 1932. Aroma × self; selected in 1924. Fruit: more attractive appearance and larger yield than Klondike, which it resembles.

Massey.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1940. U. S. D. A. 634 (Royal Sovereign × Howard 17) × Blakemore; selected in 1934. Fruit: dessert quality high; large; extremely attractive.

Maytime.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo). Introduced commercially in 1941. Missionary × Fairfax; selected in 1933. Fruit: matures a week earlier than other early varieties; firm; quality good.

Narcissa.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1933. Royal Sovereign × Howard 17; selected in 1925. Fruit: high dessert quality; early; resistant to fruit rots in the Northwest; yields high.

New Jersey 225.— See **Julymorn.**

New Jersey 311.— See **Crimson Glow.**

New Jersey 312.— See **Sparkle.**

New Jersey 347.— See **Redwing.**

Northstar.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George F. Waldo and George M. Darrow). Introduced commercially in 1939. Howard 17 × Redheart; selected in 1930. Fruit: quality high; firm; beauty above average; matures very early.

Oregon State College 12.— See **Corvallis.**

Ranger *(Texas No. 68).*— Originated in Winter Haven, Texas, by the Texas Agricultural Experiment Station. Introduced commercially in 1937. Texas × Missionary; selected in 1935. Fruit: colors evenly; ripens earlier than Klondike. Plant: flowers and fruit covered well by foliage; heavy plant producer adapted to southern conditions.

Redheart.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1932. Portia × Eureka; selected in 1925. Fruit: very good for canning; quality high; firm; color good.

Redstar.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow and George F. Waldo). Introduced commercially in 1940. Chesapeake × Fairfax; selected in 1933. Fruit: latest productive firm variety of high flavor for latitude of Washington, D. C.; attractive; most nearly resembles Fairfax. Plant: leaf-spot resistant; leaves very large.

Redwing *(New Jersey 347).*— Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (J. H. Clark). Introduced under restrictions in 1940; named in 1943. New Jersey 46 (Pearl × Aberdeen) × Fairfax; selected in 1933. Fruit: very large; firm; good for frozen pack.

Riogrande *(Texas No. 15).*— Originated in Winter Haven, Texas, by the Texas Agricultural Experiment Station. Introduced in 1937. Blakemore × Ettersburg 80?; selected in 1935. Fruit: season early; flavor good. Plant; good plant producer; adapted to southern winters. Most nearly resembles Blakemore.

Shelton.— Originated in New Haven, Connecticut, by the Connecticut Agricultural Experiment Station (D. F. Jones). (Chesapeake × Marshall) × (F_1 cross of inbred Progressive × Howard 17). Fruit: color attractive, retained after picking. Foliage healthy. Most nearly resembles Chesapeake.

Southland.— Originated in Washington, D. C., by the United States Department of Agriculture (George M. Darrow). Introduced commercially in 1932. Ettersburg 80 × Howard 17; selected in 1922. Fruit: quality high; beautiful appearance. Plant: very productive; remarkable plant growth; adapted to South.

Sparkle *(New Jersey 312).*— Originated in New Brunswick, New Jersey, by the New Jersey Agricultural Experiment Station (J. H. Clark). Introduced under restrictions in 1942; named in 1943. Fairfax × Aberdeen; selected in 1933. Fruit: good for frozen pack. Plant: very productive; last flowers on cluster usually set; highly resistant to red stele.

Starbright.— Originated in Glenn Dale, Maryland, by the United States Department of Agriculture (George M. Darrow and George F. Waldo). Introduced commercially in 1940. Chesapeake × Fairfax; selected in 1933. Fruit: season early; quality high; flavor good; firm; beauty above average.

Temple.— Originated in Beltsville, Maryland, by the United States Department of Agriculture (George M. Darrow) and the Maryland Agricultural Experiment Station (W. F. Jeffers). Introduced commercially in 1943. Aberdeen × Fairfax; selected in 1939. Fruit: earlier, firmer, and more resistant to leaf-scorch disease than Aberdeen; brighter red color than Fairfax. Plant: very free plant maker; highly resistant to red stele root disease.

Tennessee Beauty *(Tennessee No. 263).*— Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station. Introduced commercially in 1942. Patent no. 629. Missionary × Howard 17; selected in 1935. Fruit: ripens midseason to late; quality good; most nearly resembles Aroma. Plant: healthy; production good.

Tennessee No. 6.— See **McClintock.**

Tennessee No. 148.— See **Tennessee Shipper.**

Tennessee No. 260.— See **Tennessee Supreme.**

Tennessee No. 263.— See **Tennessee Beauty.**

Tennessee Shipper *(Tennessee No. 148).*— Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station. Introduced commercially in 1941. Missionary × Blakemore; selected in 1935. Fruit: an all-

purpose variety; very firm; quality high. Plant: healthy; produces heavily. Most nearly resembles Blakemore.

Tennessee Supreme *(Tennessee No. 260).*— Originated in Knoxville, Tennessee, by the Tennessee Agricultural Experiment Station. Introduced commercially in 1940. Patent no. 502. Missionary × Howard 17; selected in 1935. Fruit: flavor fine; selected for frozen pack. Adapted south of Howard 17, which it most nearly resembles.

Texas No. 15.— See **Riogrande.**

Texas No. 21.— See **Alamo.**

Texas No. 68.— See **Ranger.**

Twentieth Century Everbearing.— Originated in Cottonwood Height, Utah, by Taijiro Kasuga. Introduced commercially in 1932. Patent applied for. Berri-Supreme × Rockhill; selected in 1926. Fruit: ships well; highly flavored. Plant: yields heavily; heavy plant maker. Most nearly resembles Rockhill.

Ulrich.— See **Improved Clark.**

Valentine.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1941. Howard 17 × Vanguard; selected in 1930 from 1927 breeding. Fruit: matures very early. Most nearly resembles Parsons.

Vandyke.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1928. Open-pollinated seedling of Ontario Seedling 1467 (Dunlap seedling × Early Ozark); selected in 1922 from 1919 breeding. Fruit: matures early. Variety now lost because of susceptibility to yellows. Most nearly resembled Dunlap.

Vanguard.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1924. Pocomoke × Early Ozark; selected in 1915 from 1913 breeding. Fruit: matures early. Most nearly resembles Early Ozark.

Vanrouge.— Originated in Vineland, Ontario, Canada, by the Ontario Horticultural Experiment Station. Introduced commercially in 1938. Ontario Seedling 180115 [Admiral × Ontario Seedling 1563 (Dunlap × Early Ozark)] × Bliss; selected in 1933 from 1930 breeding. Fruit: flesh deep red throughout; excellent for frozen pack.

Wray Red.— Originated in White Salmon, Washington, by E. P. Wray. Introduced commercially about 1930. Patent no. 101. Klickitat × (seedling of Chesapeake × Campbells Early); selected about 1920. Plant: very productive in eastern Washington, being the market berry in that area.

TANGELO

Pearl.— Originated in Riverside, California, by the California Citrus Experiment Station (H. B. Frost). Introduced commercially in 1940. Imperial grapefruit × Willow Leaf mandarin; selected in 1929. Fruit: ripens very early; flesh firm; quality very good; acid and sugar similar to sweet orange; aroma unique.

WALNUT

Firstling.— Originated in the Carpathian Mountains of Poland; nuts collected there by the Rev. Paul C. Crath of Toronto, Canada; Mr. Carl Weschcke of Wisconsin procured some seeds and introduced this variety commercially in 1942. Parentage unknown. Nut: Persian (English); medium to small; shell thin. Tree: hardy; difficult to graft on native black walnut.

Schafer.— Originated in Yakima, Washington, by Wilhelm Schafer. Introduced commercially in 1940. Patent no. 494. Grown from seed brought from Austria or Rumania; selected in 1937. Nut: Persian (English); matures very early in fall; high percentage of kernel. Tree: hardy; productivity high.

WHITE SAPOTE

Dade.— Originated in Homestead, Florida, by the Florida Subtropical Experiment Station. Introduced commercially in 1943. Open-pollinated seedling of the common white sapote; selected in 1939. Fruit: flavor fair; no bitter element; shape and size uniform. Tree: bears well.

NAMES OF PATENTED VARIETIES

Patent Number	Varietal Name
4	Acme Thornless Young, blackberry
29	Montlate, cherry
30	Montearly, cherry
47	Brake, pecan
57	Scarlet Staymared, apple
61	Newtown Delicious, apple
73	Humble, pecan
74	Riland, apricot
82	Bauer Thornless Logan, blackberry
84	Rio Oso Gem, peach
85	Jonared, apple
86	Nectar, peach
94	Sweet September, cherry
101	Wray Red, strawberry
119	Fragrance, mango
125	Yorking, apple
139	Hass, avocado
173	Kim, nectarine
175	Fertile Hale, peach
184	Trauernicht, pomegranate
186	Sullivan No. 1, peach
232	Redelberta, peach
233	Howard Fisher, peach
238	Valmore, apple
258	York-A-Red, apple
261	Monroe, avocado
262	Plantz, peach
311	Empress, grape
316	Richmorency, cherry
320	Erly-Red-Fre, peach
325	Early Halehaven, peach
327	Almeda, apple
351	Early Rochester, peach
388	Wrixparent, apple
418	Sunday, peach
433	Macpherson, avocado
451	Fascell, mango
474	Minnetonka Beauty, apple
476	Harriet, apricot
494	Schafer, walnut
496	Sequoia, nectarine
502	Tennessee Supreme, strawberry
503	Ernie Fehr, apricot
507	Wiser, peach
509	Sanger Sweet, grape
512	Tennessee Autumn, raspberry
529	Robin, peach
540	Sharon, peach
549	Le Grand, nectarine
560	Crystal Red, plum
592	Glamar, peach
593	Hoffman, peach
604	Bates, peach
608	Empire Red, apple
621	Redwing, peach
629	Tennessee Beauty, strawberry

ALPHABETICAL LIST OF VARIETY NAMES INCLUDED IN LIST NO. 1

A

Acme Thornless Young, blackberry
Alamo, strawberry
All-Red-Free, peach. See Erly-Red-Fre
Almeda, apple
Amador, peach
Andora, peach
Atlantic, blueberry

B

Babcock, peach
Bates, peach
Bauer Thornless Logan, blackberry
Bellmar, strawberry
Bixby, filbert
Blakemore, strawberry
Bonita, avocado
Bonita, peach
Booth 1, avocado
Booth 3, avocado
Booth 7, avocado
Booth 8, avocado
Brainerd, blackberry
Brake, pecan
Branford, strawberry
Brightmore, strawberry
Bristol, strawberry
Brooks, mango
Brooks Late, mango. See Brooks
Burlington, blueberry

C

Carlola, filbert
Carolyn, peach
Cascade, blackberry
Cauley, apple
Chaffey, peach
Chesley, carissa
Christensen Early Elberta, peach
Coit, avocado
Collinson, avocado
Conard, apple
Connecticut 431, strawberry. See Branford
Corona, peach
Cortez, peach
Corvallis, strawberry
C. O. Smith, peach
Crimson Glow, strawberry
Crystal Red, plum

D

Dade, white sapote
Daybreak, strawberry
Dolores, filbert
Dorsett, strawberry
Double-Red Baldwin, apple
Double-Red Duchess, apple. See Red Duchess
Double Red Delicious, apple. See Starking

E

Early Halehaven, peach
Early Montmorency, cherry. See Richmorency
Early Rochester, peach
Edranol, avocado
Eleanor Roosevelt, strawberry
Ellis, peach
Empire Red, apple
Empress, grape
Erly-Red-Fre, peach
Ernie Fehr, apricot

F

Fairfax, strawberry
Fairmore, strawberry
Farida, peach
Fascell, mango
Faurot, apple
Fertile Hale, peach
Firstling, walnut
Fontana, peach
Fortuna, peach
Fragrance, mango
Franklin, apple
Fuchsia, avocado
Fyan, apple

G

Gardner, prune
Glamar, peach
Glendale, gooseberry
Golden State, peach
Gomes, peach
Graham, apple
Grove, apple

H

Halehaven, peach
Halford No. 2, peach
Hall, avocado
Halo, peach
Harpareil, almond
Harriet, apricot
Harris, avocado
Hass, avocado
Hebron, strawberry
Herman, avocado
Hermosa, peach
Hickson, avocado
Hoffman, peach
Howard Fisher, peach
Humble, pecan
Hutchison, peach

I

Idared, apple
Improved Clark, strawberry

J

Jalna, avocado
John Gardner, grapefruit
Johnson Early Elberta, peach
Jonared, apple
Jones No. 200, filbert. See Bixby
Jordanolo, almond
Julymorn, strawberry

K

Kalhaven, peach
Kara, mandarin
Kim, nectarine
Kinnow, mandarin
Klondyke Early Elberta, peach

L

La Pryor, grape
Lawrence, peach
Leeton, peach
Le Grand, nectarine
Leucadia, avocado
Lindgren, avocado
Lovell Cling, peach. See Wiser
Lula, avocado

M

McClintock, strawberry
Macpherson, avocado
Magdalene, filbert
Massey, strawberry
Maytime, strawberry
Maxine, peach
Milton, raspberry
Minnetonka Beauty, apple
Monroe, avocado
Montearly, cherry
Montlate, cherry

N

Narcissa, strawberry
Nectar, peach
Nestor, peach
New Jersey 225, strawberry. See Julymorn
New Jersey 311, strawberry. See Crimson Glow
New Jersey 312, strawberry. See Sparkle
New Jersey 347, strawberry. See Redwing
Newtown Delicious, apple
Nonpareil, filbert
Northstar, strawberry

O

Oregon State College 12, strawberry. See Corvallis

P

Pacific, blackberry
Padre, plum
Pearl, tangelo
Pedersen, peach
Pemberton, blueberry
Penryn, peach
Perfection, apricot
Plantz, peach
Pomeroy, peach
Potomac, strawberry

R

Rainbow Stripe, cherry
Ramona, peach
Ranger, strawberry
Red Duchess, apple
Red Winesap, apple
Red York Imperial, apple. See Yorking
Red Yorking, apple. See Yorking
Redelberta, peach
Redheart, strawberry
Redland, guava
Redstar, strawberry
Redwing, peach
Redwing, strawberry
Richards Early Italian, prune
Richmorency, cherry
Rio Oso Gem, peach
Riogrande, strawberry
Robin, peach
Rosy, peach
Ryerson, cherimoya

S

Sanger Sweet, grape
Scarlet Staymared, apple
Schafer, walnut
Schobank, mango
Seedless Emperor, grape. See Empress
Sequoia, nectarine
Serena, carissa
Shannon, peach
Sharon, peach
Shasta, peach
Shelton, strawberry
Simmonds, mango
Simpson, avocado
South Haven, peach
Southland, strawberry
Sparkle, strawberry
Springfels, mango
Stanford, peach
Starbright, strawberry
Starking, apple
Staymared, apple
Stuart, peach
Sullivan No. 1, peach
Sullivan, No. 4, peach
Sunday, peach
Sunday Elberta, peach. See Sunday
Sun Glo, peach. See South Haven
Sunglow, peach
Sungold, peach
Sweet September, cherry

T

Tahoma, raspberry
Taylor, peach
Temple, strawberry
Tennessee Autumn, raspberry
Tennessee Beauty, strawberry
Tennessee No. 6, strawberry. See McClintock
Tennessee No. 148, strawberry. See Tennessee Shipper
Tennessee No. 260, strawberry. See Tennessee Supreme
Tennessee No. 263, strawberry. See Tennessee Beauty
Tennessee No. Y944, raspberry. See Tennessee Autumn
Tennessee Shipper, strawberry
Tennessee Supreme, strawberry
Texas No. 15, strawberry. See Riogrande
Texas No. 21, strawberry. See Alamo
Texas No. 68, strawberry. See Ranger
Thornless Boysen, blackberry
Tioga, nectarine
Trauernicht, pomegranate
Trovita, orange
Tudor, peach
Twentieth Century Everbearing, strawberry

U

Ulrich, strawberry. See Improved Clark

V

Valentine, strawberry
Valiant, peach
Valmore, apple
Van Buren, apple. See Red Duchess
Van Fleet, raspberry
Vance Delicious, apple
Vandyke, strawberry
Vanguard, peach
Vanguard, strawberry
Vanrouge, strawberry
Vaughan, peach
Vedette, peach
Veefreeze, peach
Velvet, cherry
Vernon, cherry
Veteran, peach
Viceroy, peach
Victor, cherry
Viking, raspberry

W

Warder, apple
Washington, raspberry
Weldon, peach
Weschcke, butternut
Weschcke, hickory
Whetstone, apple
Wilking, mandarin
Willamette, raspberry
Williams, peach
Wiser, peach
Woodford, filbert
Wray Red, strawberry
Wrixparent, apple

Y

York-A-Red, apple
Yorking, apple

Sturdy Faith and Dormant Buds[1]

By W. H. Chandler, *University of California, Los Angeles, Calif.*

In troubled times like this, and in the depressive routine of normal times, we need, more than anything else I think, a sturdy faith to sustain us, a faith that to convince our minds requires no argument and to warm our hearts requires no exhortation. I make no agology for the fact that the faith I shall proclaim does not grow out of theology or philosophy but rather out of horticulture, not the horticulture of the office and the laboratory, but work with my trees and shrubs and vines: Sunday horticulture that seems to me, in some way, to release the mind. The emblem of my faith is the tree and its system of dormant buds that can grow only if buds that happen to be in more favorable positions for growth are removed. If ends of branches are removed, shoots will grow out of the older wood from buds that have grown each year only enough to keep their tips in the bark. Then when their opportunity comes, they grow vigorously. Because of this reserve of dormant buds a tree is more dependable in a destructive world. It can be broken to pieces pretty badly and will grow new parts to replace the lost ones.

This condition in the tree symbolizes my faith in humanity, my conviction that society, at least in those countries that have been able to maintain order without despotism most of the time, cannot long change in any direction except toward a richer life for the average person; for I know there are many dormant buds in human society also. I hope I may be forgiven for citing my own experience. Society has treated me rather well, better than I deserve I often think. Yet I reassure myself by thinking that if my treatment were not deserved at least partly, such an intelligent audience as this would not listen to me. But I was born in a one-room, log house that the dog could come into without having the door opened for him, was reared, with seven brothers and sisters that followed rather rapidly, in houses only a little better, and spent a great deal of the time in my early years wondering which of the neighbors I could not return an insult from because we were in debt to them. I have told these things to say this: down in that hard life I knew fifty or more children who by every test in school or at work were as capable as I or more so and whom different turns of chance have kept there, some in situations a little better than we had, some about the same, and some harder. Some of their children have shown much greater ability than I have. I'm not feeling sorry for them, or complaining about injustice to them. Chance is neither just nor unjust. In fact, I sometimes envy them for their ability to live a good life on a small income, to rear and educate their children, keep informed, vote as wisely as university professors, or possibly more so (for I'm inclined to think that, from the stand-

[1]A paper presented to a joint meeting of the members of the Synapsis Club and American Society for Horticultural Science, held at the Citrus Experiment Station, Riverside, January 3, 1944.

point of the greatest good to the greatest number, if you are naturally intelligent, you are apt to vote more wisely the less comfortable you are). I believe that for every man who started in a hard situation and has had ability enough, or luck enough, to become prominent, to be mentioned in Who's Who, for example, there are probably dozens, if not hundreds, of submerged people, dormant buds, who, with some training, could do his work as well.

People have been disturbed by the thought that war breeds the race downward, by killing off the best and leaving a nation of culls. War does enough harm, but I doubt if it has this effect to any measurable degree. Greece has been said to be a nation of culls because a long series of wars has killed off the worthy part of the population. After her performance in this war, does anyone here think she is a nation of culls? Her life was hard because her population is too large for her natural resources so that human labor is cheaper than machinery, but this is no evidence of degeneracy. And people have been disturbed because comfortable families, those of the superior people, are so small: the race is being bred downward with alarming rapidity, they think. I can't become disturbed. I am certain that there are superior people everywhere, in all kinds of business, in all groups of laborers, among the dispossessed, in the slums, and I am optimist enough to believe that there are superior people even among those who think they are superior. If some brilliant fiend should try to use all that is known about genetics to breed the race downward, I believe that, under monogamy at least, he would fail, so many worthy people are hidden in every part of society. And our social institutions are safer because of them.

If the leaders were not supported by a great army of worthy, obscure people, dormant buds, such moral progress as humanity has made would not have been possible; the leaders would have been overwhelmed by the ignorant and the selfish. There have been periods that suggest such a condition, when by comparison with the steep advance just before and just afterward men seemed to be moving downward; as, by contrast with a steep grade beyond, a part of the highway seems to slope downward when your car tells you the grade is actually upward. If we could see our ancestors just before the origin of any records we have except remnants of crude implements, I think the evidence of moral advancement would be overwhelming. I doubt, however, whether studing tribes that have remained primitive in sight of modern civilization can disclose much about the spirit of the ancestors of modern civilized races. These, I think, must have been much more intelligent and probably more restless and violent than primitive people of today. In the long process of selection by which they rose they had acquired this intelligence, which I think must have been equal to ours, and related to this, something that rather easily developed into a love of beauty in form and color and behavior, also an intense driving selfishness, and opposed to this selfishness, a protective love of each other, that Darwin called the group instinct. Of course, the righteous wrath which normally supported this group instinct was not always directed wisely, was apt to be mixed with selfishness, if we

can judge them by our own behavior. Probably sometimes the people joined in waves of what they considered righteous anger to destroy leaders who were trying to restrain the rugged individualism of some in the interest of all.

In the conflict between the group instinct and selfishness, men were not guided by written laws and recorded experience and their behavior must have been highly contradictory. I should think one of our ancestors might have fought nobly for the protection of his group one day and killed or maimed one of that same group the next day over division of a fish. If he didn't like the restraint imposed upon him for the common good, I doubt if he would have been satisfied merely to call his officer a bureaucrat or a communist or one of "them" crazy professors. I think he would have looked for a good chance to mash the officer's head in with a stone.

I do not need to say that man had not become altogether kindly when he first began to leave some written reports of his doings. Even his gods would have denounced him bitterly if he had kept as many of his conquered enemies alive as Hitler has. These gods show strikingly how man's group instinct has slowly come to have a larger place as compared with selfishness, in his thinking and aspirations at least. Early man sought mainly personal benefits from his gods, especially the destruction of his enemies. When he conquered a country and moved in, he was apt to adopt the gods of that country along with his own, hoping to obtain additional benefits. These gods were constantly changing as the culture of the people and their priests changed. Some have continued to focus the attention of the individual too much on himself, in this life or one or more lives to come, so that he does not become useful to society. Some have been used to serve the personal interest of the priests, or of a military class as in Japan. Some, under the influence of a few noble priests or prophets like those in Persia, have become magnificent beings ruling the universe in splendor and working to make human life upright and kindly.

Even the noblest of them all, Yahweh, God of Israel, was at first a stern god of ruthless force, destroying their enemies and, like the Greek gods, enjoying the odor of burnt offerings; but as the country developed in the ways of peace, the prophets made him into a god of love and mercy and justice and wholesome living, who said through the Prophet Amos, "Even though you offer me burnt offerings, and your cereal offerings, I will not accept them. And the thank offerings of your fatted beasts I will not look upon, but let justice roll down like waters and righteousness like a perennial stream." Every good feature in any god was put there by the minds and the group instinct and the sense of beauty of people. These gods need not be physically real to be sacred; they are sacred because they express the good sense and love and beauty in the human heart, the vision of noble priests and prophets that have given warmth and color in the developing, special souls of peoples and the great soul of humanity.

Our primitive ancestors probably had their hearts uplifted and their bodies comforted by Ma Joads going about with competent hands administering to their wants, ignoring their brutality and encouraging

them in their hardship to expect better luck tomorrow. And they probably had leaders whose rugged sureness of behavior appealed to their sense of beauty and their group instinct as strongly as such men appeal to us now; and wandering bards probably sang their praises for awhile after their death. But until priests were set apart there was probably no accumulation of the teachings and examples of such people; each noble life and each rich experience was probably forgotten within a generation or two. Since men have learned to write, all such lives and experiences have gone on inspiring generation after generation, that which appeals to our sense of beauty and our group instincts being kept, while the ugly and the sordid parts were forgotten or ignored. We are inspired by the noble lives and thoughts of ancient Greece and spared the stench of slavery and other evils of their time. The lives of all people enter into this soul of humanity, each generation leaving it a nobler support to the group instinct, a stronger bulwark against ruthless selfishness. Lives that find their way into the light of history and become conspicuous in the soul of humanity have received inspiration and support from contact with good, inconspicuous people, dormant buds.

Truth discovered by research enters into the lives of the people and its beauty is recorded for all time in literature and art; the drudgery of the laboratory today becomes beauty in the soul of humanity tomorrow. Because our discoveries enter the basic part, the masonry of the soul of humanity, we should report them with modest reverence. We want a foundation not of spongy lava thrown up by workers each anxious to strut about the biggest pile, even if it is the trashiest, but, rather, of dressed stone each piece placed carefully where it belongs in the structure.

When we look into life for the influence of this growing human soul we see it in education of children of the poor as well as those of the rich, in better care of the unfortunate, in fairer dealing with labor, in all efforts to give equality of opportunity, in better discipline and at the same time more individual freedom and more human kindness; the group instinct has been slowly, sometimes painfully, restraining selfishness.

But you may say: "How can you have faith in people with what is happening now?" I believe that there never was a time with more reason for sturdy faith. Did anyone think before this war that people could show the magnificent courage that the English showed in fighting on after France fell or that the Russians have shown? And did any nation ever have more reason to choke with pride in the good sense and courage and daring of its young men and their officers than we have today?

I have said for twenty years that I believe no other young people could ever have been as fine as those that have been coming out of our schools. Some people say that, because these young people seem to think they should be able to earn a living in eight or nine hours a day and have several hours to enrich their lives, they are soft. I know some of them have expected more than life is apt to give and for less work than life requires. But would anyone here like to be out in the

Pacific or in Italy competing with them and demonstrating to them that they are soft? And think of the young women on the trains, standing halfway across the country, to see their husbands at the training camps on Christmas, or parents and wives proud when their sons and husbands make good records that will cause them to be accepted in some of the most dangerous but exacting services. There is a tough goodness with a stern loyalty in humanity, put there by thousands of years of men struggling together against raw nature for survival. Anyone who is too busy with his selfish interests, or with smart criticism, to see these facts is missing the noblest things life has to show him. In this war we see goodness and loyalty as we never saw them before.

Furthermore, I think we have better reason than ever before for faith that nations will pool their forces to keep order in the world so that people in each nation will be free to use nearly all its resources to enrich their lives as much as possible within its own boundaries: we know now better than ever before how urgently we need such force, Nations now allied in active struggle against Germany and Japan will have a richer common heritage than allied nations have had following preceding wars. The airplane and other mechanized fighting equipment give heroism a chance to be seen. Certainly so many nobly heroic deeds have not been publicly recognized in other wars. This heroism of their young men fighting together is a sacred treasure of all allied nations and will be a richer, more endearing treasure when it has entered into beautiful literature and as it goes through the years with increasing beauty in motion pictures. Creeds and philosophies, things to argue about, divide people. Literature and art inspired by a rich common heritage unite them in thoughtful, reverent enjoyment. The lives of our heroes entering into the soul of humanity to repair the rents made by Hitler and Tojo will be among its noblest, most beautiful parts.

We can have faith in the triumph of good in humanity in spite of the evil we know exists; in fact, life is richer because of the imperfections in it. I liked the part in one of George Bernard Shaw's plays where the bishop advised people always to give the devil a chance to state his case, for I have come to believe that the devil has a rather strong case. He stands for selfishness, and a degree of selfishness is socially necessary: for the most diligent care of each individual. Furthermore, we need something to struggle against. If in man the instinct of self-preservation, selfishness, and the group instinct, human love, were so nicely balanced that there would be no conflict, so that we could just enjoy our goodness comfortable like pigs enjoy their fatness, would life be very interesting? Perhaps the richest part of life is knowledge of the great people that have been in it. If selfishness were no problem, we should never have heard of the thundering righteousness of the Hebrew prophets or of Jesus; they would have been just other nicely balanced men. And what use would we have had for Thomas Jefferson or Lincoln or Horace Greeley, or for the thousands of supporters who made their work possible, dormant-bud Jeffersons and Lincolns and Greeleys out among the people. The only

changes I want to see in man are those he makes himself struggling upward in response to the soul of humanity and his group instinct.

I believe, however, that we may be approaching a time when the group instinct will require the support of a stern, reverent self-discipline, if selfishness is to be prevented from doing lasting harm. Selfishness and grouches and hatred tend to thrive by the side of heroism during war, and especially just afterward. After the Civil War and after the other World War we had periods when we trusted tariff and hatred and a superiority complex to solve all our social problems, and we paid dearly for it. This war is due at least in part to the grouches against our leaders cultivated for political reasons in the other war, grouches that prevented us from trusting them when they urged us to supply our share of the force and conference necessary to keep order in the world. We need the group instinct magnified and selfishness suppressed more than ever now. I believe the decisions we make at the end of the war would ensure a richer future for us if eaoch morning everyone of us would read the incomparably beautiful poem by Saint Paul: "Though I speak with the tongues of men and of angels and have not love I am become as clanging brass and tinkling cymbal."

"And though I have prophecy and understand all mysteries and all knowledge and have not love, I am nothing.

"And though I bestow all my goods to feed the poor and though I give my body to be burned and have not love, it profits me nothing.

"Love is long suffering and kind, love envies not, love boasts not, is not arrogant, does not act rudely, is not self-seeking, is not ill-tempered, thinks no evil, rejoices not in wrong doing but rejoices in truth . . . . And now abideth faith, hope, love, these three; but the greatest of these is love."

Then think what it might mean to our future if each one, after reading this would reflect:

Though we fight with righteous anger and incomparable efficiency, subdue our enemies and destroy the fiends that debased them, we may still lose all we are fighting for and send our children or grandchildren into a more devastating war if our hearts are not kindled by love of humanity and guided by sympathetic understanding of the difficulties encountered by our leaders and those of other nations.

It might help in the war too. I believe our effectiveness in the war will be influenced much more by how much we love each other and are willing to sacrifice for the common good than by how violently and blindly we hate the Germans and Japanese.

My faith tells me that we shall not fail this time. Hatred may be the normal reaction of people to perplexing problems: when one group of distant leaders advocates taking serious risks and making daily sacrifices to keep order in the world and permit the human soul to grow in effectiveness and beauty and another group advocates the temporarily easier if more dangerous way of looking out for ourselves and despising the rest of the world, perhaps a majority of people would take the less responsible way if they did not have advice from dormant buds, neighbors as intelligent as the leaders and less driven

by partisan necessity. Even some of these wise neighbors were not convinced before that force to keep world peace was necessary. Peace and some order had been maintained by the navy of Great Britain and the armies of her allies for so long before the other war that, even after it, most of us were not convinced that the airplane and the submarine had so weakened that force that our help had become indispensible if civilized life was to continue. All kindly, intelligent people must be convinced now and will convince their neighbors. And the soul of our nation with that of humanity will live.

Human love supported by the blundering experiences of people, the patient searching of scholars, the courage and vision of statesmen and their dormant-bud supporters, the wisdom and stern righteousness of prophets, the daring loyalty of heroes, all set in beauty by the live words of the gifted writer, the rhythm and grandeur of the poet and the musician, the grace and variety of the actor, the design of the artist, the reverent services of the clergyman: the soul of humanity, sublime, and yet so earthy that it increases in richness from the life of even the humblest of us. Whether my part is visible through the oil-immersion lens or not even to the electron microscope, it will find its true place regardless of any padding of it or strutting about I am foolish enough and irreverent enough to do; and to have even the smallest part in that noble structure is all the immortality that I want.

Three Decades with California Deciduous Fruit Problems[1]

(Presidential Address)

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Horticulturally, California is unique in the diversity of its crops, soils, topography, and climate. The challenge thus presented to the pomologist is perhaps unequaled in any similar area. I shall outline briefly certain problems which have been presented during thirty years of intimate contact with the deciduous tree-fruit industry of the state; little or no mention will be made of the small fruit, grape, and subtropical industries, neither will pest control nor processing problems be discussed. In the judgment of the pomologist the solution of practically all the problems that I shall describe is incomplete; nevertheless, sufficient progress has been made so that the orchardist can in most instances apply a practical remedy.

California fruit growing is an intensive and specialized industry, the orchard does not form an integral part of a general farm enterprise. With few exceptions the orchardist is interested only in fruit production. The relative isolation of the state has made necessary an independent attack on many of its pomological problems. Logically the activities of the Experiment Station first dealt with the improvement of orchard practices, but with a tripling of the acreage and production during the past thirty years new problems of specialized nature have been presented. The extension of orchard planting into new and untried areas and the increasing age of the trees in old established districts have been most important in presenting ever new difficulties.

There are 1½ million acres devoted to fruit culture in California which in 1939 constituted a little over 20 per cent of the state total harvested area of crops. This acreage returned about 45 per cent of the state total gross income from farm crops as compared with about 13 per cent for the nation as a whole. Of 21 important fruit and nut crops raised in the United States, California ranks first in the production of 15, and many of these crops are raised either exclusively or in large measure only in that state. Undoubtedly, a favorable climate is responsible for this concentration of fruit acreage which produces about 40 per cent of the national crop of fruit and nuts.

Varieties

The Franciscan fathers initiated horticultural experiments in California with their Mission gardens beginning about 1769 at San Diego and extending almost 500 miles north to the Sonoma Mission, 40 miles northeast of San Francisco. During the 80 years elapsing between the establishment of the first mission and the discovery of gold, much was learned as to the general adaptability of various pomological

[1]A portion of the material presented herewith was originally prepared for a forthcoming "History of California Agriculture" to be published by the University of California Press. The reader is referred to this volume for greater detail regarding the different problems and a discussion of specific fruits.

species to California, but it remained for the great influx of settlers subsequent to 1848 to introduce named varieties. Of 100 varieties of deciduous tree fruits now of greatest commercial value, one third were introduced before 1860, another third are of California origin, and the remainder have come in from time to time during the past 80 years.

Other factors being equal, the variety determines the ultimate success or failure of a fruit industry. The first pomological activity of the University of California was the establishment of a variety orchard at Berkeley; the purpose being to correct the nomenclature of the fruits already in cultivation, to supply scion wood and plants for distribution, and to introduce new varieties. In 1874 there were 584 varieties of fruit trees, 73 of grapes, and 95 various small fruits.

In 1893, there were growing at Berkeley and four substations (Jackson, Paso Robles, Pomona, and Tulare) 1,158 varieties of fruit trees, including the standard commercial varieties. As indicated by Wickson, Berkeley was not a suitable place to test varieties; and by 1895 the orchard was being removed. In 1890, however, trees had been propagated to plant at the substations, which were in turn closed by 1906. The acquisition of land at Davis made possible the continuation of variety tests, with plantings begun in 1908. By 1926 about 1,350 named varieties of deciduous tree fruits and nuts were under cultivation.

Wickson in 1917 stated that none of the early University tests had led to commercial planting of new varieties; no pear tested had replaced the Bartlett, and no olive proved better than the Mission. Wickson's statement holds true in 1944; no new introduction into commercial planting has come from the University tests of named varieties. The collections have, however, been of inestimable value for instruction, varietal studies, and breeding material, as well as a means of saving individual growers the great expense of testing these less satisfactory varieties.

Pollination

The Division of Pomology was organized in 1913 to study the cultural problems of the deciduous fruit industry, and a year later began a series of studies dealing with the pollination requirements of the various deciduous fruits. These have continued, with new varieties or with old ones that have taken on a new importance, so that now definite information is available for most varieties grown in California. This work would have been greatly handicapped without the extensive variety collections.

Breeding Deciduous Tree Fruits

As an offshoot of the pollination studies, almond breeding was initiated in 1918, and in 1938 the United States Department of Agriculture in cooperation with the University released two new almond varieties (Jordanolo and Harpareil) for commercial planting.

At the Southern California Pathological Laboratory at Whittier, peach trees of the South China race leafed and fruited better than

the commercial varieties. In 1907 pollen from these South China peaches was used in certain crosses which finally in 1933 resulted in the introduction of the Babcock peach which has proved resistant to "delayed foliation". In 1939 the University introduced other peach varieties adapted to mild winters. It is too soon to evaluate these relatively new varieties.

In 1928 peach and nectarine breeding was started at Davis, and hundreds of seedlings have been fruited. So far no new varieties have been named, but several show commercial promise. Sweet cherry breeding begun some years later has given more positive results with the release of one variety — Lambush. This is a Bing type ripening somewhat earlier than Black Tartarian. Several other seedlings are most promising for shipping, canning, or brining.

The United States Department of Agriculture and the University have for several years cooperated in a general fruit breeding program in which distinct progress has been made, particularly with almonds, apricots, plums, and pears. Facilities for the work have been much improved by the gift of the Wolfskill Experimental Orchards at Winters in 1936, with soil and climate admirably suited to stone-fruit culture, and by the moving of the federal fruit-breeding program from Palo Alto, in 1941, to a unified headquarters at Davis.

Until recent years, the harvest of clingstone peaches extended over a period of approximately six weeks. Weaknesses, however, in the Tuscan (early) and Phillips Cling (late), resulting in the removal of many orchards of these varieties, and the continued planting of mid-summers, has narrowed the delivery of the bulk of some 400,000 tons (1944) to a period of three weeks. Since the canning season of clingstone peaches overlaps with Bartlett pears the load on the canneries during August and the first half of September is tremendous. Breeding work by the United States Department of Agriculture at Palo Alto (initiated in 1920), resulting in a number of new clingstone varieties (Fortuna, Shasta, and Corona among others) and more particularly the selection and testing of chance seedlings by the University offers relief with high quality varieties now being planted which will extend the seasons at both ends.

Pruning

Pioneer California fruit growers early developed systems of pruning markedly different from those used in other sections of the United States. These differences consisted essentially in more detailed and severe cutting. Apparently many of the early orchardists came from southern European countries where fruits for centuries have been cultivated intensively in gardens rather than extensively in orchards. The severe and repressive pruning necessary to develop espaliers and cordons was apparently transferred to standard orchard trees and, with California's advantageous soil and climate, gave fairly satisfactory results; but pruning investigations, begun in 1915, have shown that a less severe cutting brings increased yields without loss of quality. This improvement in production per acre has helped keep the fruit-

grower in business despite increased costs of production and transportation coupled with decreased returns per ton of fruit.

Climate and Deciduous Fruit Culture

Rest Period:—From the inception of fruit growing in California, occasional seasons have occurred when there was a heavy drop of apricot and peach fruit buds and a slow, straggling start of new growth of most deciduous fruit and nut trees which resulted in decreased crops and dwarfing of the trees. This condition generally has been called "delayed foliation". The symptoms of this disorder have been more severe and more frequently observed south of the Tehachapi Mountains than in the northern part of California; and for certain crops (apricots, walnuts) has resulted in a shifting of acreage to the north. In the late 1920's, the University was able to demonstrate that this trouble was due to lack of sufficient chilling during the winter months to break the "rest" — a bud characteristic of most deciduous trees and shrubs. Some kinds of plants require much more chilling than others; whereas 3 weeks or less is enough for the almond, 3 months or more of chilling temperature may be required before buds of some varieties of apple will open normally. Artificial breaking of this rest by sprays is a distinct possibility. Progress has been made in the breeding of varieties, especially peaches and apricots, with less chilling requirements.

Annual Initiation of Growth:—The annual blooming date of any variety of deciduous fruit is apparently dependent upon its rest requirements and high enough temperatures to initiate growth. California winters generally are so mild in deciduous fruit districts that growing temperatures occur before cold units sufficient to break the rest have accumulated. These facts present a problem of delicate adjustment of species and varieties to winter and spring temperatures. Thus the last 20 years has witnessed a tremendous shift from south to north in the location of walnut orchards, together with a change in varieties to suit the colder winters.

The selection of varieties for cross pollination makes it necessary that the varieties in question should both have the same rest requirements and start growth with the same initial temperature. As a case in point, the Winter Nelis pear is not always a satisfactory pollenizer for the Bartlett, which has a more profound rest than the former variety. Also the Bartlett will start growth at lower spring temperatures than the Winter Nelis.

Fruit Ripening:—Careful growth records of apricots and pears in California seem to indicate that in the case of the former fruit, time of ripening is determined by the accumulation of total heat units but that total heat units and maturity of Bartlett pears are not necessarily correlated. Work with stone fruits indicates that relatively warm temperatures during the first cycle of growth are more effective in securing early maturity than during the second or third periods. Unfortunately such intimate studies have not been conducted with the pome fruits, but certainly in California no general statement can be made that pears in all districts will reach the same maturity in a

definite number of days after full bloom. More recent studies, as yet unpublished, have developed rather accurate formulae using blooming date and early season temperatures for forecasting first harvest dates for apricots and prunes.

Shape of Pears:—A former cannery specification that the length of No. 1 Bartlett pears must be 1⅓ times the breadth resulted in great losses to growers in certain years and districts. Growth and temperature records seem to indicate that length of Bartlett pears is determined by temperatures existing during the early part of the growing season; the lower the temperature the longer the pear.

Irrigation, Cultivation and Fertilization

Irrigation:—The early 1850's were notable for the introduction and rather widespread plantings of many varieties, and for the beginning of irrigation in commercial orchards, although some of the Mission gardens had been watered during the dry season before this time.

One problem confronting the early fruit growers, many of whom were accustomed to eastern climatic conditions, was whether to irrigate or not. Apparently the theory of conserving moisture by establishing a dust mulch by frequent cultivation was widespread even then, and irrigation was not favored by many orchardists. According to Wickson, irrigation was nearly abandoned as early as 1856, and facilities were left unused. In the *Transactions of the California Agricultural Society* in 1859, some writers advised irrigation of orchards, whereas others opposed it. The opponents mentioned the quality of the products of nonirrigated fields, but not the productivity of such plantings. The idea that fruit from nonirrigated orchards is better has unfortunately persisted to the present time.

The use of water continued to increase, despite the claims that frequent cultivation could be substituted for water, and during the next two decades agencies were formed to build structures for bringing water to new areas. Many mistakes were made, the most common being the use of too much water, with the resulting rise of water tables, the accumulation of salts, and the flooding of low lands. Hilgard called attention to these dangers attending the copious use of water. Methods of application were studied. At the same time, farmers and governmental agencies were securing information on the amount necessary for the various crops, the number of applications needed on different kinds of soil, the depth of penetration after an irrigation, and similar problems.

Cultivation:—In 1919 the University began to study the irrigation of deciduous orchards in the Santa Clara Valley. This work was supplemented by experiments at Davis and by studies on the behavior of fruit trees growing in large weighable containers. The resultant data published in 1927, threw much light on plant and soil moisture relations and showed that cultivation was ineffective in conserving moisture. They showed that the amount of water which can be stored in the soil where most of the roots are located is limited, and usually is exhausted in 4 or 5 weeks in mature orchards during the growing

season; that the movement of water in the soil by capillarity is comparatively slow; that the loss by evaporation is confined largely to a shallow depth; and that cultivation does not influence the losses of moisture by evaporation from the bare surface. Since that time, continued experimentation has revealed that soils have two important moisture-holding properties: first, the field capacity, or amount of water held against the force of gravity after the free water has drained away; second, the permanent wilting percentage, or the amount of water still held by the soil when the plants wilt. The wilting percentage represents the lower limit of available water, below which the plant cannot function normally until the supply is replenished. Lack of available soil moisture during the growing season generally reduces the rate of growth of fruit, if the shortage occurs before the fruit has reached full size. Repeated shortages of available moisture in successive years is usually indicated by trees smaller than irrigated ones in similar situations.

Fertilizer Applications:—Early-day growers generally believed that no application of fertilizer was necessary in deciduous orchards. The opinion held for many years; and while comparatively new land was being planted, the theory was valid. Recently, however, certain kinds of trees on some soils have showed need of fertilizers. Studies show that response may be obtained quite frequently with nitrogen, but rarely or not at all with potassium and phosphorus. Also important is the discovery of the lack of sufficient amounts of several other elements, long thought to be unimportant for plants — namely, zinc, copper, boron, iron, and manganese. In most cases the latter elements are required only in very small amounts, which may be added to the soil, or, in some cases, may be injected into the tree or sprayed on the foliage.

Nutritional Problems

Fruit-growing in California has involved problems characteristic of expanding and intensified industries. The importance of a plant disease is usually conditioned by the economic loss involved. Thus, a disease that destroyed much of a crop or many of the trees over a large area would receive attention. If it affected the trees or crop in only a limited area or caused only a small loss, little heed might be paid it if the prices were not high; the affected area might be avoided in planting, or the loss accepted as a necessary evil. If, however, prices were high, the losses might be great, and the disorder important. Consciousness of disease is conditioned, too, by the probabilities of learning its cause and has somewhat kept pace with the information regarding the plant's reactions. Naturally, therefore, the physiological or nutritional disorders of trees received much attention soon after 1920, for in this period the fruit industry was expanding rapidly and knowledge of plant reactions was being improved.

Little-Leaf:—For many years trees growing in certain areas of California have had small leaves spaced close together on the stem so that the branch presented a rosette or witch's-broom appearance — the disease called "little-leaf", "rosette" in deciduous, "mottle-leaf"

in citrus trees. Investigations revealed, soon after 1930, that zinc should be added to such trees by spraying, injection into the trunk, or other methods. Thus many sick and poorly producing trees have been caused to grow normally.

Prune Dieback:—During the 1920's certain newly matured prune trees in the upper Sacramento Valley began to show a die-back condition. This area in 1930 contained some three million bearing prune trees (23 per cent of the total California bearing prune acreage at the time) and about 900,000 young trees (27 per cent of the state's non-bearing prune acreage). Trees with heavy crops showed scorching of leaves, dying-back of the branches, and eventually death. Through investigations begun in 1927, the University associated the disease with a low potassium supply in the soil, and its severity, with heavy crops. Losses of trees were distinctly lessened, and the returns increased, by a rather severe pruning, accompanied in seasons of heavy set by fruit thinning. Although no way has been found by which these soils can be made desirable for prunes, the improvement caused by pruning and thinning has greatly decreased the losses in orchards already established.

Lime-Induced Chlorosis:—In the early 1920's pear trees in the lower areas near the bay in the Santa Clara Valley were affected with chlorosis. For some years previous, the water table in the Valley had been lowering, so that the roots of the pear trees had been able to grow deeper and to penetrate soil very high in lime. In consequence, iron, though plentiful, had become unavailable, and the leaves had failed to produce chlorophyll. Whenever iron in an available form, such as iron citrate or iron tartrate, could be supplied, the chlorotic condition was cured.

Exanthema:—Another deficiency disease of pear and apple is exanthema. This disorder, which causes scorched leaves and poor growth on trees in the Santa Clara Mountains and Moraga Valley, results from a lack of copper. Very small amounts, as little as ¼ gram per tree, have restored normal growth.

Boron:—Though boron has proved necessary for plant growth and apples, olives, and pears have been found to suffer from a deficiency, there are areas in California where trees suffer from an excess. This condition has been brought on or seriously aggravated by use of irrigation water with a boron content so high that the element has gradually accumulated in the soil. Now that investigations have identified both excess and deficiency symptoms and have indicated an upper limit for the boron content, growers can determine whether or not a source of irrigation water is suitable.

Rootstocks

The great diversity of varieties, species, soils, and pests in California makes the rootstock problem of the deciduous fruit grower most complex. In Placer County, where fruits are raised almost exclusively for eastern shipment, an average orchard of 20 acres may contain twenty varieties divided among five or six species planted on soils varying greatly in fertility, depth, and drainage.

Perhaps no where else do fruit growers so frequently change the variety and even the species of fruit they produce. These changes which are largely made by topworking (either grafting or budding) have resulted in the accumulation of much empirical information relative to the affinity existing between different varieties and species, as well as certain stock-scion relationships. Time will permit the mention of only a few of the problems.

Nematodes:—In many areas of the San Joaquin Valley, where the soil was light and sandy, peach trees could not be successfully grown because of the common garden nematode. Conceivably, since certain species like the apricot did not suffer, there might be some peach varieties whose seedlings could likewise grow in the presence of nematodes. The seedlings of several hundred varieties of peaches were tested; and three of them — the Yunnan, the Shalil, and the Bokhara — were found in 1929 to be nematode-resistant. Since the seedlings of these varieties have proved to be good rootstocks for almond and peach, trees may now be planted on hundreds of acres not previously available.

Black-End:—Pear growers have long hoped for blight-resistant varieties and stocks. Naturally, therefore, *Pyrus serotina*, the Japanese rootstock which seemed more resistant than the French stock previously used, was employed almost exclusively in the heavy pear planting between 1917 and 1925. About 1925, however, numerous young trees produced fruits so blackened, hardened, or cracked around the calyx end as to be worthless. The disease was called "black-end" or "hard-end". The trees so affected were all on Japanese stock. Only certain trees were producing the diseased fruits, and these continued to do so each year; the disease did not spread throughout the orchard. Though no cure has been found, a program has been developed whereby the grower can mark the unprofitable trees, remove them, and replant with trees on stocks that do not produce black-end. No black-end fruits have been observed in the Beurre Hardy even when grafted on stocks known to produce black-end on other varieties. In California, Hardy is second only to Bartlett in acreage.

Replanting Peaches:—The peach tree has a relatively short profitable life. After about twenty years the production of an orchard usually falls below a profitable tonnage. About 1937 a rather large acreage of peach trees began to reach the end of profitable returns. Since these orchards were in areas well adapted to peach growing, it was desirable to replant. Many of the replanted orchards, however, grew poorly: the young trees were low in vigor or failed to live. Often the replanted orchards were slow in coming into bearing and contained trees of different ages because many replants were necessary. The available information indicates that the bark of the roots of the old trees leave in the soil some alcohol soluble material toxic to new peach roots. Apricot, plum, cherry, and pear replants on old peach soils seem to be unaffected.

Own-Rooted Santa Rosa Plums:—Most plum, prune, and apricot varieties make a satisfactory union and growth when propagated on peach, and on this root are apparently less susceptible to injury by

bacterial gummosis. No satisfactory explanation of this and other possibly correlated facts is available. In certain districts when the Santa Rosa plum propagated on peach is allowed to form scion roots the trees, within a few seasons, cease to bear, become subject to bacterial gummosis, and eventually die. If the scion roots are severed soon enough the tree becomes productive again and tends to remain resistant to the disease. In such sections it is common practice to plant peaches and later bud the Santa Rosa in the scaffolds to avoid any possibility of scion roots. In other districts scion-rooted Santa Rosas set satisfactory crops and remain healthy.

This is one of the many isolated and interesting observations that has been made in the study of rootstocks in the propagation of fruit trees and another example of where exact information of possible causes is yet lacking.

Fruit Development

Growth Studies with Drupaceous Fruits:—Measurements of diameters, volumes, and weights all indicate a general periodic type of growth for most stone fruits in which three phases are generally well recognized. The first period is one of early, rapid growth, the second is one of slow growth, and the third is characterized by the most rapid increase in size which terminates with maturity. These periods are correlated with definite embryo development so that it is possible to distinguish between the various phases by a macroscopic examination of the seed. These growth cycles are so determinate that certain field practices are now timed in accordance with their occurrence.

Thinning of Stone Fruits:—Field trials show that the size of fruit at harvest is progressively smaller as thinning is delayed, but give no evidence that the time of pit hardening is a critical one, after which the benefits of fruit thinning are terminated or markedly reduced. This earlier misconception is also contradicted by evidence secured from a study of the growth of stone fruits.

Another conception which field trials have shown to be inaccurate is that increase in size of individual fruits secured by thinning will compensate for loss in total number of fruits harvested. Any thinning reduces total harvested tonnage. The relationships of premiums paid for larger fruit, the additional labor costs necessary to attain these sizes, and total yields are primary factors determining the thinning program. Time of maturity, reduction in number of culls, and prevention of tree breakage are other factors to be considered. In California with a normal fruit set, peaches and shipping plums will always be thinned, apricots may or may not — depending on the proposed market, but premiums for larger sized prunes have never been sufficiently great to interest growers in thinning this fruit to obtain the larger sizes.

Split-Pit and Gumming of Peaches:—Competition or overproduction often raises the standards that have previously been acceptable. Such a condition probably affects the losses experienced from split-pit and gumming of peaches. Beginning about 1927 the demand for large fruit no doubt intensified both these disorders, since both are associated

with high growth rates that may be caused by light crops or injudicious thinning. Gumming, furthermore, has proved to be a varietal weakness characteristic of the Phillips Cling, but the losses from this disorder as well as from split-pit can be reduced by postponing thinning until the fruit is well into the second period of growth.

The Ultimate Size of Clingstone Peaches:—Sufficient data have been secured from the investigations of split pit and gumming to demonstrate that with cling peaches a definite correlation exists between the average size at pit hardening and the average size at harvest. This fact has a direct practical application. The grower can take a representative sample of his fruit at reference date (initiation of pit hardening), weigh it, and from a prepared table determine the average size. This average size will indicate the type of thinning problem he has to handle. For example, if the average size is about 32 mm, he will know that the fruit will be difficult to size and consequently the thinning job must be very well done. Or if the sizes are larger than 36 mm, 39 mm for example, he will know that saleable size will be easy to make and his thinning problem will be opposite of the first situation. At a later date, but before it is too late, he can take another sample and determine from its average size whether the fruit is making suitable growth. If the thinning has not been heavy enough, the error can be remedied by removing additional fruit. Fortunately when sets are heavy and sizes small, early and relatively heavy thinning are not so likely to result in gumming and split-pit. The data for distribution of sizes at harvest show that an average size of about 66 mm is necessary in order to have 90 per cent of the fruit above 60.3 mm (2⅜ inches, the minimum saleable size). Such a situation results in maximum tonnage of saleable fruit.

Fruit Handling and Storage

Distances from the centers of population make California commercial fruit growing and transportation problems inseparable. Even by 1860 production greatly exceeded local demand. Not until the completion in 1869 of the transcontinental railroad could the industry expand. In 1900, shipments of deciduous and citrus fruits had increased to 50,000 carloads, and today (1944) average annual refrigerator-car shipments of fruits approximate 175,000.

The determination of the maximum stage of ripeness at which different deciduous fruits can be harvested for shipment, best methods and most desirable temperatures which can be reached by precooling and continue to exist in transit, and of their effect upon ripening, are problems which have been studied for twenty years by the University independently and in cooperation with the United States Department of Agriculture. The first head of the Division of Pomology, A. V. Stubenrauch, was a pioneer in the field of pre-cooling and fruit transportation.

As transportation is an inseparable part of fruit growing in California, so refrigeration is vital to transportation. With California-grown apples, two serious transportation and storage troubles have presented themselves; bitter pit on the Gravenstein and internal

browning in the Yellow Newtown. California's apple industry is built upon these two varieties.

Despite much research work, the exact cause of bitter pit is still to be determined. Results since about 1931 demonstrate, however, that maturity at harvest time and rate of ripening have an important influence on its severity.

Internal browning is a storage disease peculiar to the Yellow Newtown produced in the Pajaro Valley. Stubenrauch traced in 1912 the trouble to low storage temperature; and in 1923 his early findings were confirmed, and it was also pointed out that growing temperatures, size of crop, and maturity at harvest time must be considered. Later work indicates that still other factors are involved. A storage temperature of 36 degrees F instead of 32 degrees will reduce the amount of flesh injury, and of 40 degrees will prevent it. Since, however, fruit stored in a normal atmosphere at this temperature ripens rapidly, some additional means must be found to prolong its storage life.

After early work in England and several season's experimental tests by the University with carbon dioxide atmospheres, the first commercial storage room in the United States for holding of apples in carbon dioxide was constructed at the Watsonville Apple Growers' Cold Storage Plant in 1938. In an atmosphere containing 10 per cent carbon dioxide, fruit may be held in good condition at 38 to 40 degrees F for as long a time as at 32 degrees, at which browning is usually severe. This method, therefore, promises good results for the storage of Pajaro Valley Yellow Newtowns.

I trust that the above discussion has demonstrated that the peculiarities of the California climate, topography and soils present many horticultural problems not encountered elsewhere. The situation is unlike that in many sections of the country where the solution of a problem secured in one state is equally valuable to several neighboring states. Pomologically, California has been forced to be largely self-sufficient.

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